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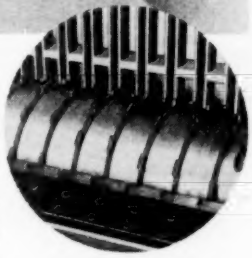

Close-up of Cutters and Combs. Cutters rotate within slots of Bar and Comb

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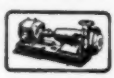

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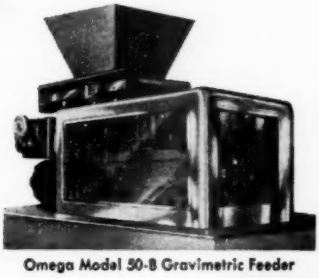

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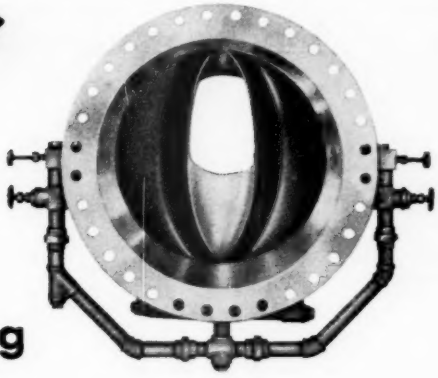

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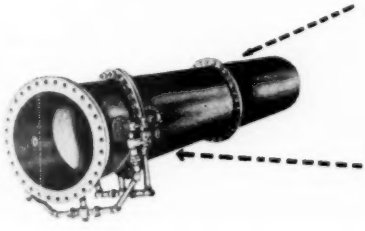

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Association	*Place*	*Time*
Canadian Institute on Sewage and Sanitation	General Brock Hotel, Niagara Falls, Ont., Can.	Oct. 26–28, 1953
New England Sewage and Industrial Wastes Association	Wannamoisett Country Club, 96 Hoyt Avenue, East Providence, R. I.	Nov. 5, 1953
Pacific Northwest Sewage and Industrial Wastes Association	Hotel Chinook, Yakima, Washington,	Nov. 5–7, 1953
North Carolina Sewage and Industrial Waste Association	Sheraton Hotel, High Point, N. C.	Nov. 9–11, 1953
Nebraska Sewage and Industrial Wastes Association	Hotel Capital, Lincoln, Nebr.	Nov. 12–13, 1953
Oklahoma Water, Sewage and Industrial Wastes Conference	Okla. A & M College, Stillwater, Okla.	Nov. 16–20, 1953
New York Sewage and Industrial Wastes Association	Hotel New Yorker, New York, N. Y.	Jan. 21–22, 1954
New Jersey Sewage and Industrial Wastes Association	The Traymore Hotel, Atlantic City, N. J.	Mar. 10–12, 1954
Arkansas Water and Sewage Conference	Marion Hotel, Little Rock, Ark.	March 22–24, 1954
Kansas Sewage Works Association	Broadview Hotel, Emporia, Kansas	April 7–9, 1954
California Sewage and Industrial Wastes Association	Hotel Senator, Sacramento, Calif.	May 5–8, 1954

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in conjunction with

Ohio Sewage and Industrial Wastes Treatment Conference
Netherland Plaza Hotel, Cincinnati, Ohio

October 11–14, 1954

Briefs from the YEOMANS GUARD

Sewage Treatment Plant Helps Sell Home Lots at Better Prices in New Florida Subdivision

- **Unique plan of private financing provides for plant operation by city of St. Petersburg on pay-for-itself basis**

That a modern, efficient sewerage system and sewage treatment plant is a powerful help in selling subdivision lots is being effectively demonstrated by J. & P. Land Developers, Inc., in the promotion of "Garden Manor"; new 242-acre, 800-home tract at St. Petersburg, Florida. The sanitary system alone attracted enthusiastic buyers, and increased lot values by $450 to $500, say the developers.

Furthermore, upon completion of the development, the entire system and plant will be operated and maintained by the City of St. Petersburg on a self-supporting basis. A tax amounting to 30 per cent of the home owner's water bill is to be levied for 20 years; 60 per cent of that revenue will go to the developers to repay their $250,000 investment in the sewerage system and treatment plant; and the remaining 40 per cent will finance operation and maintenance by the city.

Main feature of Garden Manor's sewage treatment plant—complete, modern, ready to serve the new community—is a Yeomans "package" unit, combining a primary tank and digester.

As a "package" solution to a basic sanitation problem, and as an effective use of private capital, to achieve public benefits, Garden Manor offers a valuable pattern for similar developments, according to Samuel G. Johnson, Mayor of St. Petersburg; and Dr. Robert E. Rothermel, Director of Public Health of Pinellas County, praises the whole project as a wholesome example of "intelligent co-operation by public officials and commercial developers."

If you are interested in taking small-community sewage treatment out of the "necessary evil" class and making it a profit producer, write for information on Yeomans "Packaged" Sewage Treatment Plants.

90% B.O.D. Removal in "Aero-Filter" Plant at Plant City, Fla.

How's this for a letter?

"The Florida State Board of Health joins the City of Plant City in its pride in having such an excellent sewage treatment plant." The letter to T. J. McCall, City Manager, continues "and certainly Plant City has set an example which would be very profitable for other cities to follow."

In a later letter the State Board of Health added, ". . . we now have almost a year's operating data on this plant . . . and apparently it is achieving a B.O.D. removal in excess of 90 per cent."

This all-Yeomans waste treatment plant, built around an "Aero-Filter" and four dual Streamline Sludge Collectors, was designed by Alan B. Pimm, Consulting Engineer of Tampa, Fla., to meet the needs of the present population of approximately 10,000 with provision for possible future population growth to 15,000.

The happy sequel to this success story is the fact that numerous other communities *are* following Plant City's example. They're specifying Yeomans treatment equipment and getting high efficiency at low cost.

The Yeomans Guard, published several times a year, is a compendium of news and useful information covering the pumping of materials and the treatment of wastes, both domestic and industrial. We shall be pleased to send you the current issue if you'd care to have it. Ask your local Yeomans Representative—listed in the telephone book yellow pages under "Pumps"—or write direct.

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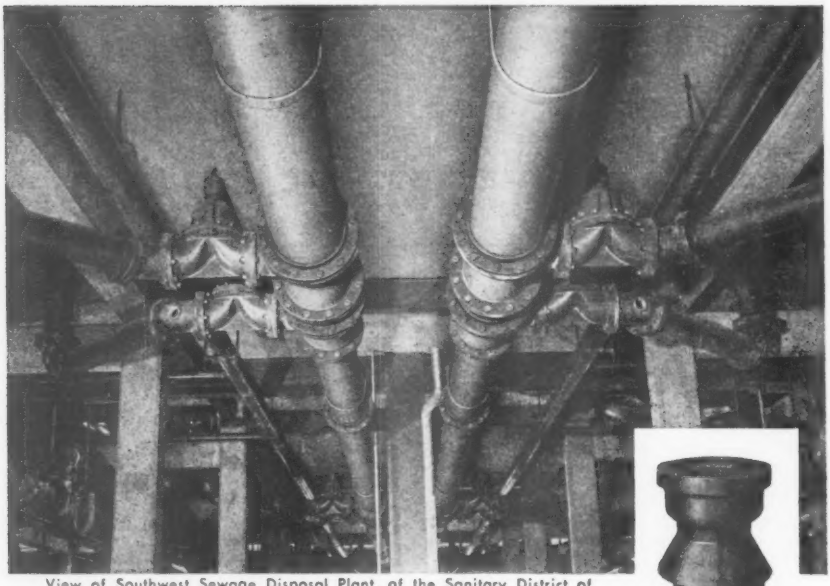

View of Southwest Sewage Disposal Plant, of the Sanitary District of Chicago, Stickney, Illinois . . . where Clow Cast Iron Pipe was furnished to meet exact requirements.

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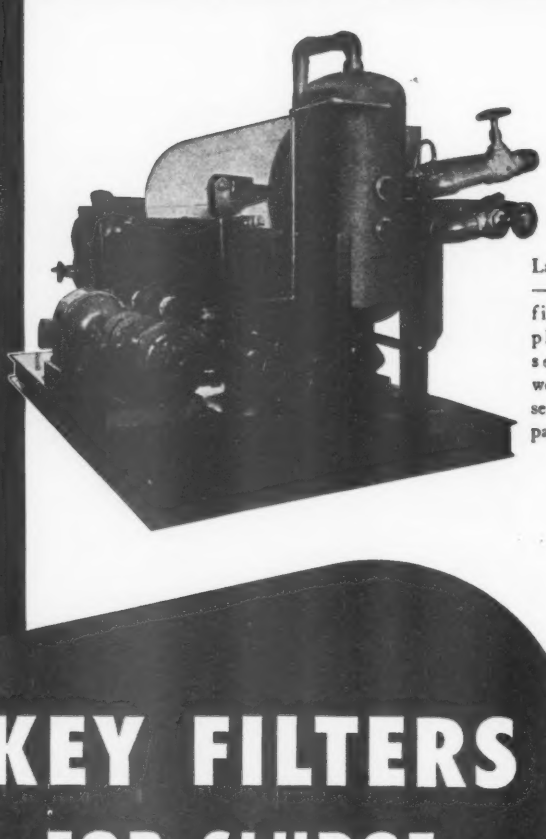
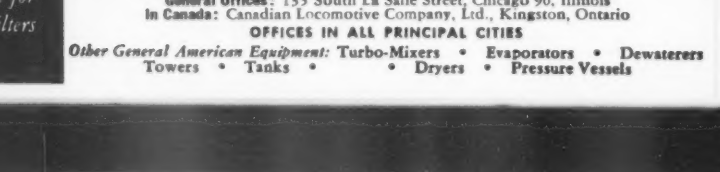


Large or small —a Conkey filtration plant can serve you well. Left, a self-contained package unit.

CONKEY FILTERS FOR SLUDGE

66 Conkey Sludge Filters installed in one plant of Chicago Sanitary District. Built to exacting specifications and rigid design requirements.



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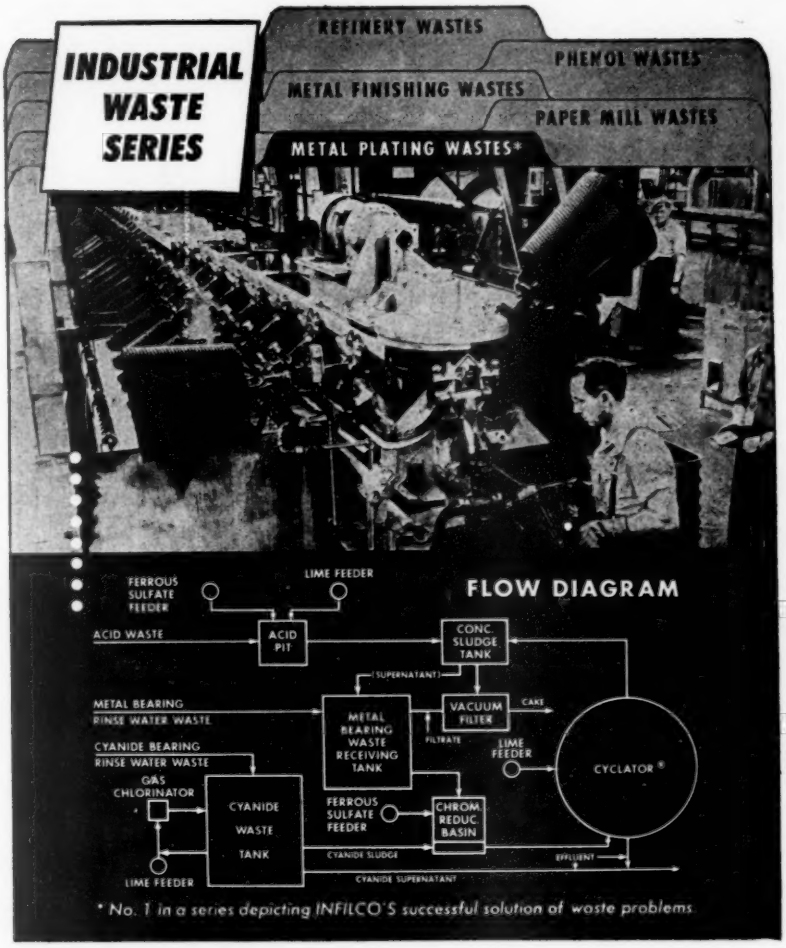

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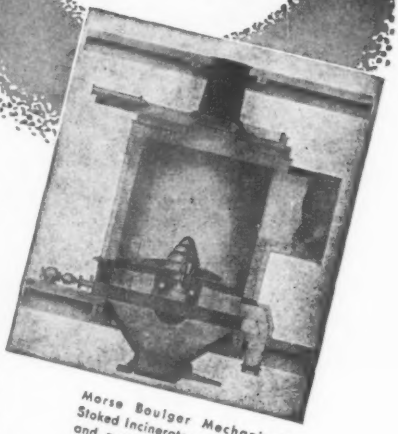

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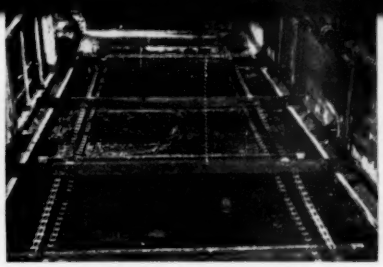

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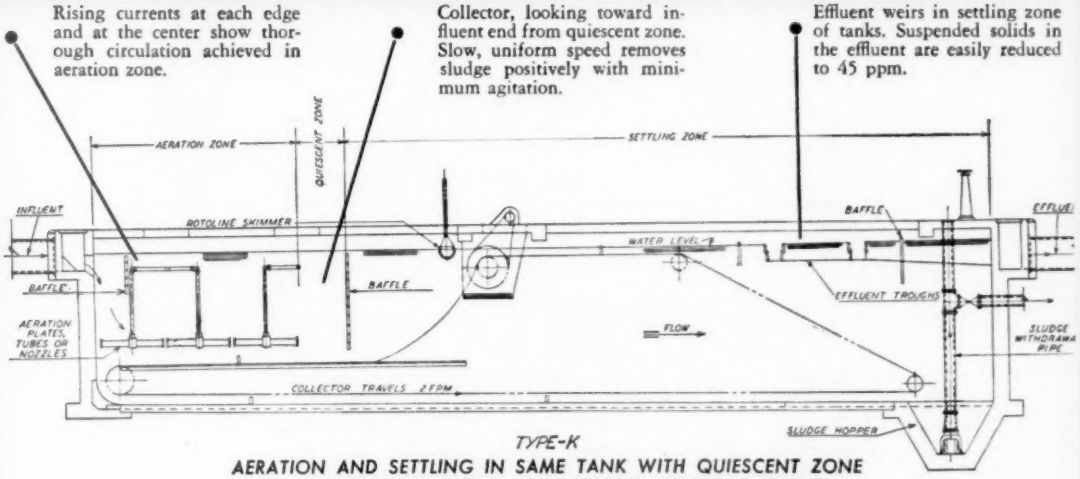

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 25 **October, 1953** **Number 10**

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Sewage Works

BIOCATALYSTS AND WASTE DISPOSAL

I. Fundamental Biochemistry of Waste Disposal *

By Ross E. McKinney †

Department of Sanitary Science, Southwest Foundation for Research and Education, San Antonio, Tex.

During the past year there has been a tremendous increase of interest in the use of various organic biocatalysts to solve waste disposal problems. But, like many new ideas, the product has preceded technical information as to its proper use and ultimate value. This has posed quite a problem to the operator and to the engineer in deciding the value or lack of value of the various biocatalysts. Proper evaluation of the biocatalysts can be made only in the light of the over-all biochemistry of the waste disposal processes and the effect that these biocatalysts have on the biochemical reactions. It is the purpose of this paper to review the biochemical reactions and the effect of two types of biocatalysts on such reactions occurring in waste disposal systems.

Previous Work

The two major types of organic biocatalysts now on the market are concentrated enzymes and concentrated bacteria. Treatment of liquid organic wastes by the use of enzymes or special strains of bacteria is not new, but has been the object of research for many years. Rudolfs (1) studied the effect of the enzymes trypsin, pepsin, and lipase on the anaerobic digestion of sewage solids and on the treatment of sewage by the activated sludge process. He found that there was no beneficial effect on either process over that of the normal control. Wooldridge and Standfast (2), Ingols (3), and Watanabe (4) have all made studies on the various enzymes in waste disposal systems.

Ever since Butterfield (5) established the biological theory of activated sludge on a sound basis, efforts have been made to speed purification of wastes through the addition of pure cultures of bacteria. Ruehhoft *et al.* (6)(7)(8), Butterfield and Wattie (9), and McKinney and Horwood (10) have shown that mixed cultures tend to bring about stabilization of sewage at a faster rate than pure bacterial cultures. This fact has caused the emphasis to be placed on the synergistic relationship of certain bacteria (11). For the most part, all previous work on the effect of enzymes and bacteria on the stabilization of wastes has been based on definite theoretical concepts. Without such theoretical studies it would be impossible to determine the effect of these biocatalysts on a waste disposal system in advance.

Microorganisms

The basic units of any biological disposal system are the microorganisms

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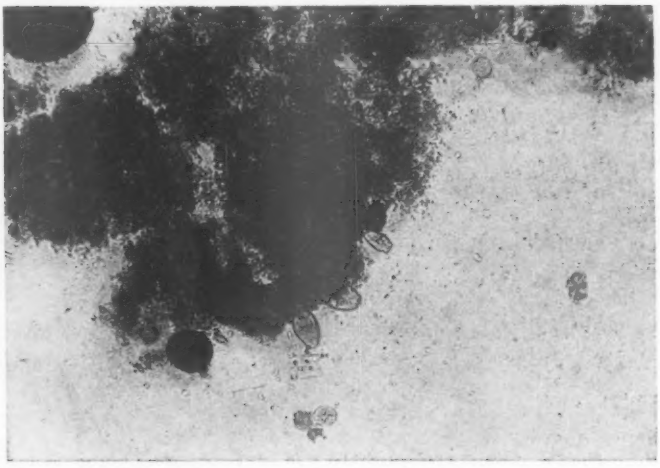

FIGURE 1.—Photomicrograph of typical activated sludge, unstained (100 ×).

which live in the system. Figure 1 is a typical photomicrograph of activated sludge. The masses are predominately bacteria, organic colloids, and inorganic colloids. Also visible are normal protozoa. In some systems fungi are present. The stabilization of the organic matter in the waste is entirely dependent on these microorganisms. To bring about the necessary biochemical reactions, the microorganism makes use of enzymes, which can be considered as the fundamental units of biological purification.

In considering the biochemistry of the waste disposal processes, one must always keep in mind the interrelationship of the microorganisms and their enzymes and the factors which affect them. The major factors are concentration of substrate, concentration of organisms, concentration of enzymes, concentrations of end products, pH, temperature, oxidation-reduction potential and inhibiting substances.

An activated sludge system represents the most complete biological waste disposal system in use and will be used as the basis for discussing the biochemical reactions. The biochemistry of the various units is the same whether the system is for partial or complete treatment.

Collection System

Since biological action starts before the wastes enter the sewer, it is at this point that the biochemical reactions are important. The presence of complex organic matter stimulates the microorganisms automatically to excrete extra-cellular enzymes. These extra-cellular enzymes hydrolyze the complex organic compounds to simple molecules that can pass through the bacterial membrane. Intra-cellular enzymes break the simple molecules down further to furnish energy to the microorganisms, as well as building blocks from which to synthesize new protoplasm. The waste products resulting from internal metabolism are excreted back into the surrounding liquid.

The amount of oxygen available for use by the microorganisms is very limited at this point and is soon depleted. The resultant metabolism is anaerobic. Figure 2 graphically illustrates the path of anaerobic metabolism. Fortunately, the energy process resulting in anaerobic metabolism is very inefficient. The majority of the organic

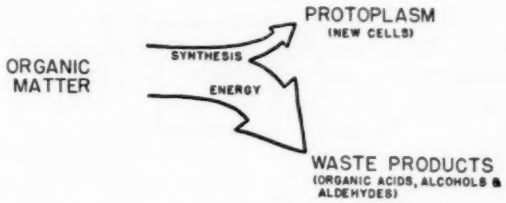

FIGURE 2.—Schematic diagram of anaerobic metabolism of organic matter by bacteria.

matter metabolized must go to furnish the organisms with energy and only a small fraction of the organic matter can be used to synthesize new protoplasm. The waste products from anaerobic metabolism are predominately organic acids, alcohols, and aldehydes, many of which are quite odorous. These waste products still represent almost all of the B.O.D. of the original waste.

If the collection system is long and the waste is retained for a considerable period, biological action can become quite extensive. The addition of more bacteria or of hydrolytic enzymes would increase the rate of biological action and the rate of formation of the odorous end products. The only way to reduce anaerobic action during collection is to keep biological action at a minimum. This can best be accomplished by the addition of bactericidal agents early in the collection system. The addition of bactericidal agents after biological action has become quite strong is of little value.

Primary Sedimentation

Consider the activated sludge system shown in Figure 3. The excess sludge is returned to the primary sedimentation tank, where it is mixed with the incoming sewage. The excess sludge is a highly active biological mass that settles quite readily and in the primary sedimentation tank helps to flocculate and absorb the colloidal solids from the incoming sewage. But the excess sludge contains hydrolytic enzymes, which start to hydrolyze the complex sewage solids. Because there are not enough microorganisms in the primary tank to utilize the breakdown products, the hydrolyzed compounds pass through to the aeration tank and the settled solids are pumped to the digester.

The addition of bacteria would result in little benefit as to increasing the B.O.D. removal. The majority of bacteria would be flocculated and removed before they could bring about much change. If the organisms were maintained in the settled sludge too long, detrimental anaerobic conditions would result.

Adding hydrolytic enzymes would bring about the breakdown of the complex solids to soluble compounds, which would pass on to the aeration tank. If the aeration tank was overdesigned it could absorb the additional load. On the positive side, there would be a reduction in the amount of solids sent to the digester.

Aeration

The primary effluent is mixed with returned sludge as it enters the aeration tank. Since breakdown of the complex solids has already started, the microorganisms have a readily available source of food for energy. Growth of new organisms is the resultant of the metabolism of this food. Simultaneously, the presence of more complex organic matter stimulates the microorganisms to excrete more extracellular enzymes in order to obtain additional food. Oxygen is supplied continuously in the aeration tank and is responsible for the resultant metabo-

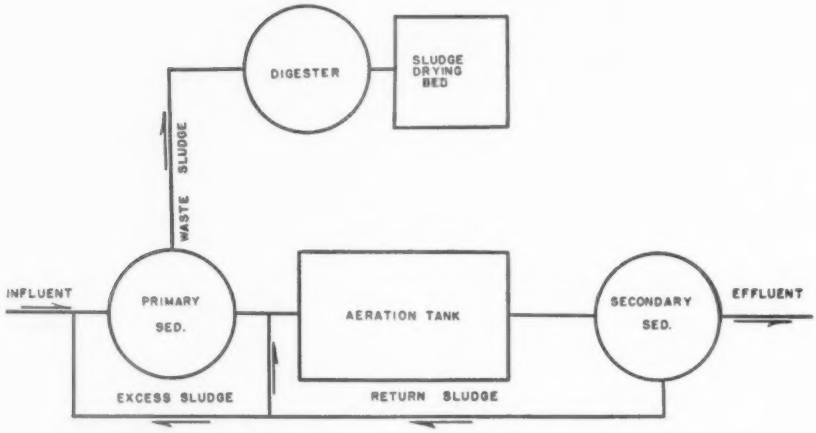

FIGURE 3.—Schematic diagram of an activated sludge system.

lism being aerobic rather than anaerobic.

Figure 4 schematically represents aerobic metabolism of organic matter as it occurs in the aeration tank. Aerobic metabolism is an efficient energy reaction and results in a greater production of protoplasm than does anaerobic metabolism from a given amount of organic matter. As an example of the energy reactions, glucose undergoes the following changes:

Thus it can be seen that 30 times the energy is obtained from aerobic metabolism of one mole of glucose than from anaerobic metabolism. This energy reaction is important from the standpoint of production of new cells. The waste products from aerobic metabolism (carbon dioxide and water) do not exert an additional B.O.D., as do the waste products from the anaerobic reaction.

Adding bacteria to the aeration tank

Anaerobic:

$$\underset{\text{(glucose)}}{C_6H_{12}O_6} \rightarrow \underset{\text{(lactic acid)}}{2CH_3CHOHCOOH} + \underset{\text{(energy)}}{22.5\ \text{Kcal.}}$$

Aerobic:

$$\underset{\text{(glucose)}}{C_6H_{12}O_6} + \underset{\text{(oxygen)}}{6O_2} \rightarrow \underset{\text{(carbon dioxide)}}{6CO_2} + \underset{\text{(water)}}{6H_2O} + \underset{\text{(energy)}}{674\ \text{Kcal.}}$$

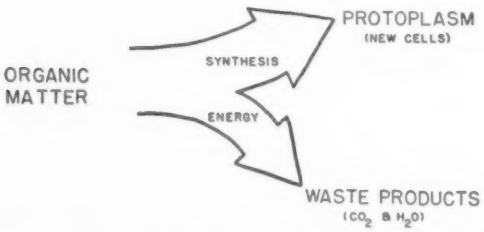

FIGURE 4.—Schematic diagram of aerobic metabolism of organic matter by bacteria.

seems the most logical way to increase the efficiency of the system. But this is not always the case. A given amount of organic matter can support only a given amount of organisms. If there are less organisms in the system than can be supported, the organisms will grow. It is in the growth phase that the maximum rate of utilization of organic matter occurs, the rate of utilization of organic matter during the growth phase being approximately 50 times that during the stationary phase. If the number of organisms equals the number which can be supported, no growth occurs and the organisms are in the stationary phase. If more organisms are added to the system than can be supported, there is a dying off.

The addition of hydrolytic enzymes increases the rate at which the complex organic matter is broken down, provided there is not already a sufficient concentration of enzymes present. The ideal case would be the addition of both hydrolytic and oxidizing enzymes, as the organic matter would be completely decomposed to carbon dioxide and water without the formation of protoplasm. This is the ultimate goal of any enzymic treatment.

Final Sedimentation

The mixed liquor enters the final sedimentation tank, where the sludge flocculates and settles out. The sludge is a highly active biological mass and must be removed from the tank as rapidly as possible to prevent anaerobic conditions, which must be avoided at this point. The efficiency of the entire system hinges on the rapid recovery and re-use of the active biological mass. The settled sludge is returned in part to the aeration tank, with the remainder going to the primary sedimentation tank and then to the digester. Bacterial additions at this point can be of no help. Hydrolytic enzymes can hydrolyze some of the fine solids which do not settle and thereby produce a nice clear effluent that will impress the casual observer. But the hydrolyzed organic end products are passed to the receiving body of water and must be stabilized at that point.

Anaerobic Digestion

The digester operates under anaerobic conditions, as illustrated in Figure 5. The complex solids are pumped from the primary sedimentation tank to the digester. Immediately, the hydrolytic enzymes begin to decompose these solids. The first step follows the path of anaerobic metabolism set forth earlier. The end products of this step furnish the food for the second and most important step in the digestion process. A second set of bacteria, the methane producers, are able to take the organic acids, alcohols, and aldehydes produced and convert them to methane and carbon dioxide. The methane can be recovered and burned, with or without the recovery of heat energy. Digesters must be de-

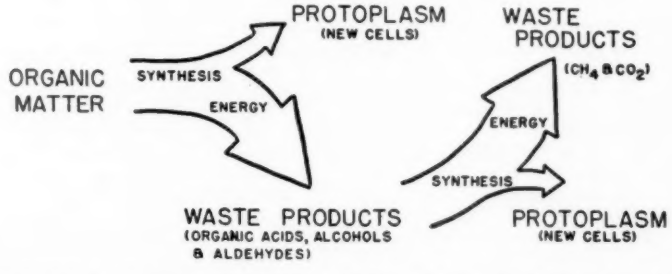

FIGURE 5.—Schematic diagram of biological digestion of organic solids.

signed and operated for these two distinct types of organisms, which must work together at all times if maximum efficiency is to be maintained.

Adding bacteria to the digester affects it in the same manner as addition of bacteria in the aeration unit. The results are much more pronounced, however, as most digesters are not properly designed or operated. Most digesters are operated on a semi-batch-wise proposition, even though it appears to be a continuous operation. As a result, the two groups of bacteria are in a constant state of fluctuation. Adding more bacteria can usually swing the equilibrium in the direction it needs to go, with an increase in digester efficiency. Unless the operating kinks are stabilized, however, this does not provide a permanent solution and the additions of bacteria must be made on a continuing basis.

The addition of hydrolytic enzymes could, in effect, eliminate the first type of organisms, provided the breakdown was complete to the stage required by the methane bacteria. This is feasible with hydrolytic enzymes. With one type of organism eliminated, the operation of the digester would be stabilized with the addition of fresh solids and the enzymic hydrolysis of those solids.

The efficiency of the biological waste disposal system is dependent on the design and operation of that system, because the biological equilibrium which is established is dependent on these two factors. For a given set of conditions, the most efficient biological system will be established without the aid of biocatalysts. However, the biological conditions which prevail may not be the most efficient from the standpoint of stabilizing the organic waste being treated. The addition of catalysts to such a system results in an apparent increase in efficiency, but unless their use is continued the system will revert back to its normal equilibrium conditions. A biological disposal system which is designed properly and operated according to the design principles will operate at the maximum efficiency without the use of additional organic catalysts.

Until the engineer has a clear understanding of the fundamental biochemical principles affecting the particular waste disposal problem at hand, it is virtually impossible to properly design the waste disposal system to operate at ultimate efficiency. Biocatalysts will be used to supplement design efficiency until the ultimate is achieved. It is not economically sound to purchase and add a biocatalyst to a system which can in itself achieve that goal.

Summary

The fundamental biochemistry of a waste disposal system as applied to activated sludge is discussed in relationship to the normal biochemical reactions and those created by the addition of such biocatalysts as concentrated enzymes or concentrated bacteria.

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FREE CHOICE GARBAGE DISPOSER ORDINANCE AT AURORA, COLORADO

A municipal ordinance recently enacted at Aurora, Colo., not only requires installation of garbage disposers in all new construction, but permits owners to select the garbage disposer of their choice on the basis of individual preference as to brand and type. The only restriction is that the buyer's choice must meet the minmium qualifications set forth by the ordinance. Aurora, a suburb of Denver, has a population of more than 25,000 and is primarily a city of homes and small businesses.

The ordinance resulted from a year-long study by a special committee seeking to eliminate garbage cans from the city streets, improve the beauty and sanitation of the city, reduce the incidence of disease by an expected lower fly and rodent count, and prevent increase of garbage collection costs. The committee was able to use the studies made by neighboring Denver, which has been investigating means to remedy the garbage collection problem for years, as well as to gather operating data and opinions from other cities investigating or using garbage disposers.

By making no attempt to dictate the brand of garbage disposer that shall be used the Aurora ordinance follows the terms of the general proposal adopted by the National Association of Plumbing Contractors at their 1953 convention, which declared against socialization of garbage disposers. In addition to requiring use of the units in new construction, the ordinance gives a measure of official approval to the garbage disposer and is expected to increase installations in renovation and modernization work. It is not the objective of the ordinance to make Aurora a garbage-free city overnight, although city officials believe this goal can be attained over a period of years.

APPLICATION OF MOLECULAR FILTER TECHNIQUES TO THE BACTERIAL ASSAY OF SEWAGE*

I. Proposed Technique

By Alexander Goetz

Associate Professor of Physics, California Institute of Technology, Pasadena, Calif.

A bacteriological technique permitting rapid and accurate quantitative estimation of the bacterial contents of waste water—if possible, without necessitating elaborate laboratory facilities—has been for many years a desideratum among the industries and authorities concerned with the highly diversified problems arising from the necessity of waste water control. The methods possible with the use of the molecular filter membranes (MF),† as resulting from research and developments by the author and his collaborators during 1947–51 at the California Institute of Technology after prototypes originating in Germany during World War II, were first introduced into the public health field for evaluation studies in 1951. The interest has been focused mainly on raw and treated water supplies intended for consumption; and a large variety of nutrient formulations, laboratory techniques, and instrumentation have been elaborated and published (1) (2) (3) (4) (5) (6) (7) (8) (9).

However, no specific effort has been made yet to present the basic method and its particular modifications to those who are interested in bacterial assays of waste waters. Therefore, it is the purpose of this paper to present in brief the various aspects in the MF technique which are generally not in the foreground when the assay of relatively pure water supplies is concerned.

Basic Nature of MF Process

The molecular filter membrane presents a paper-like thin sheet of a dry-wet stable gel of a mixture of cellulose ester polymers of very high porosity (75 to 80 per cent) and, what is most significant, of an unusual uniformity of effective pore size. The MF type developed for hydrosol assays (HA-type) has an effective pore diameter of about 0.5 micron and a pore number of approximately 1×10^8 per sq. cm. The membranes contain no fibrous constituents or binding agents. Consequently, they act very differently from filter papers or other filter agents, inasmuch as during the passage they remove suspended matter, and with it bacteria, quantitatively from the sample (the filtrate is therefore sterile) in a relatively short time. The retained deposit remains on the surface of the membrane, whereas the interior of the MF remains almost free of retained matter. The filtration, therefore, separates the organisms entirely from their former environment—a significant point in view of the sometimes highly inhibitory nature of components occurring in waste waters.

The filter membrane, after having passed a given quantity of the sample, is then transferred onto a bacterial nutrient, which in general is contained in a pad of porous paper. The nutrient diffuses into the surface and

* Presented at 25th Annual Convention, California Sewage and Industrial Wastes Assn.; Santa Barbara, Calif., April 22–25, 1953.

† Commercially available under the trade names "Isopor" and "Millipore."

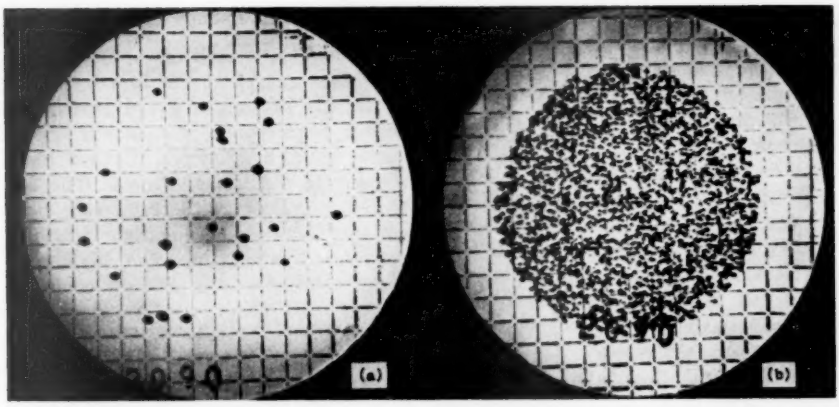

FIGURE 1.—MF cultures of *E. coli*: (a) 24 colonies after 16-hr. incubation at 37° C.; (b) 2,400 colonies after 12-hr. incubation at 37° C. (Note beginning of confluent growth.)

produces a rapid colony development of the bacterial cells retained on the surface. Due to its peculiar pore structure, the MF minimizes cross diffusion of inhibitory agents between colonies, and consequently allows for the development of mixed cultures with only minimum mutual inhibition. For this same reason, a relatively high colony concentration can be obtained (see Figure 1), which is an advantage, as it reduces the number of serial dilution steps.

Under suitable conditions the bacterial growth on the MF surface is much more rapid (especially for coliforms) than on liquid or semi-liquid media. This has been attributed to the fact that the metabolic by-products developed during the growth do not deteriorate the nutrient, as the colony develops above rather than within the nutrient. An accurate count can be obtained in general already overnight (that is, after 12 to 16 hr.).

Significant for an application to sewage assays is that, after the filtration of the sample, the remaining bacteria can be "washed" with various sterile solutions (of surface-active agents, thiosulfate, etc.) in order to remove completely inhibitory residues which could prevent the growth development of the organism. This is effected simply by filtering a quantity of the ster-

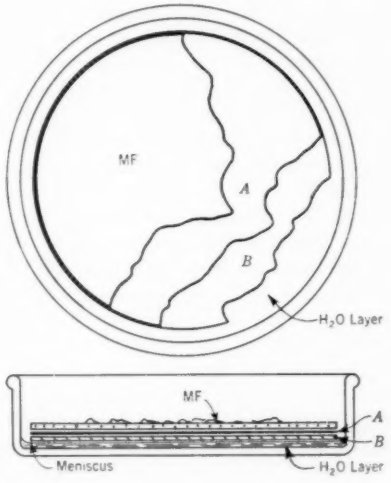

FIGURE 2.—Scheme of MF-nutrient schedule arrangement: MF after filtration is placed on porous leaf A, impregnated with a measured quantity of a generally stimulating nutrient. A is attached to leaf B, impregnated with a partially inhibitory nutrient. Both are placed in glass dish which carries 2 to 3 ml. of water for rehydration and transfer upward through MF for nutrition of bacteria on MF surface. (From Ref. 5.)

ile solution through the residue on the MF after the sample has passed.

Another consequence of the same situation is that the MF can be transferred during the incubation period from one nutrient to another, which permits the application of a "nutrient schedule" (4)(5), during which the organisms are subjected in the initial growth period to a general stimulating nutrient, whereas 2 to 3 hr. later a selectively inhibitory agent is applied. In this case the viable recovery can be substantially increased.

Finally, the incubated membrane can be dried and kept as a permanent record, in many cases without loss of characteristic colony appearance (Endo sheen).

The actual performance of an MF filtration, due to already standardized equipment, is a simple operation: namely, a predetermined quantity of the sample (not less than 10 and not more than 1,000 ml.) is filtered through the sterile MF, which is placed in an MF filter holder, which latter is sterilizable without autoclave (5). The vacuum is applied in the usual way through an aspirator or hand-operated pump.

The MF membrane is then transferred onto one or two nutrient pads consisting of the neutral porous paper, which have to be impregnated with a given quantity (about 2.5 ml.) of the sterile medium. The MF is transferred after the first 2 to 3 hr. of contact with the stimulating medium to the second pad, which contains the differentiating agents (2). The change of nutrient is automatic with the use of prefabricated dehydrated "nutrient schedules" (5), which require only 2 ml. of sterile water for rehydration prior to use (see Figure 2).

The (2-in.) Petri dish containing pads and membrane is then covered with a tight-sealing plastic film or a loose cover carrying a certain amount of water and put into an incubator as described elsewhere in detail (2).

Bacterial Assays of Sewage

It has been stated in the MF literature that one of the main advantages of the MF technique is the greatly reduced requirement for sterile glassware, simplification in dilution technique, etc. Although this is true for water supplies with relatively low counts, certain modifications must be considered when unknown high bacterial concentrations, as they occur in sewage and other waste waters, are encountered.

The standard membrane area used for filtration is 9.6 sq. cm. (1.5 sq. in.), upon which is imprinted a grid pattern wherein each square represents 1/100 of the filtering areas, so that if heavy growth occurs the total count is facilitated by an average count of a small number of squares and multiplication by 100. In spite of the favorable conditions of growth development, even in very closely adjacent colonies, there exists a limit to the capacity for growth support on the MF. This limit, depending upon the type of organism, the rapidity of its growth development, etc., lies between 500 and 1,000 for the area, although under favorable conditions much higher counts (up to 30,000) have been successfully computed. Particularly for the differentiating media for the coli-aerogenes group (such as Endo and EMB type), a reliable count should not much exceed 300 organisms (7) in the presence of high concentrations of noncoliforms. This limitation narrows the range of coliform concentration accessible by one particular test portion filtered to 1 to 300.

Although the sample quantity theoretically is unlimited, suspended matter will, of course, ultimately produce complete clogging on the membrane. Hence, the sample volume has to be so small that only partial, but not complete, clogging occurs. This imposes a lower limit on the sensitivity of the test. If, for instance, a water sample with a high concentration of suspended

matter is found to be clogging at 100 ml., the sensitivity limit lies at 1 organism per 100 ml. If it clogs at 10 ml., the sensitivity is accordingly 1 organism per 10 ml.

For purely technical reasons it has proven impracticable to filter a quantity of less than 10 ml. through the MF. This condition, combined with a maximum bacterial density (300 per MF), limits the range within which an undiluted sample can be used to 3,000 per 100 ml. If higher bacterial concentrations are to be expected, the following dilution series is recommended as the most efficient procedure, resulting in a maximal range of information with the least number of filtration steps which still overlap each other sufficiently to be reliable:

Step	Portion (ml.)	Dilution	Range (org./100 ml.)
A	300	undiluted	0.3–100
B	200	2 ml. of A (10^{-2})	50–15,000
C	100	1 ml. of B (10^{-4})	1×10^{4}–3×10^{6}
D	100	1 ml. of C (10^{-6})	1×10^{6}–3×10^{8}

Hence, with only 3 dilutions and 4 filtrations a range can be bridged that in normal procedure requires 7 dilutions and at least 10 different portions.

Concentrometric Filtration

In order to increase significant information with the least expenditure of material and labor, an entirely new mode of MF application recently has been developed. More detailed accounts are published elsewhere (10), only a brief description being presented here.

In principle the method involves a filter apparatus, the "concentrometer," which deposits on the MF a graded deposit (wedge), the measurable density of which ranges from to 1 to 75,000. It bridges, therefore, a concentration range of almost 10^5. The apparatus consists of a relatively simple MF holder, in which a rectangular membrane attached to a prefabricated frame of paper with scale is held in vertical position while the sample flows horizontally through the MF from a container of special shape. As the water level in the container is lowered during filtration, lesser and lesser fractions of the membrane will be passed by the water. Consequently, the deposit on the lower part of the MF will become increasingly heavier and denser. The interior shape of the container, which determines the mathematical function according to which the wedge-like deposit is formed on the membrane, is calculated to provide for an exponential density increase in close analogy to a serial dilution of 4 (8) steps. The MF carries a logarithmic scale (Figure 3). After the deposit is incubated, the number of the bacterial colonies will, of course, vary with the density of the deposit. The zone on the membrane where the first bacteria occur indicates the concentration in the sample when correlated with the preprinted scale on the frame. The direct scale reading provides, thus, for reliable information closely comparable to that of MPN, and actual counting is restricted to a relatively small number of colonies (20 to 30) as long as the concentration in the original sample was correctly estimated within a factor of about 75,000, which is normally the case.

In this type of filtration, a fixed total volume (300 ml.) of sample water is filtered. The zone of the first occurrence of growth for any concentration of bacteria is determined solely by the prefabricated and therefore unalterable shape of the container. It thus eliminates two common sources of error by the operator—namely, the judgment of the sample quantity necessary for giving reliable results within the range of bacterial counts prevailing in the sample, and the error involved in the range which, if at all, will produce premature clogging of the MF, because the indication is not affected by partial clogging of the MF

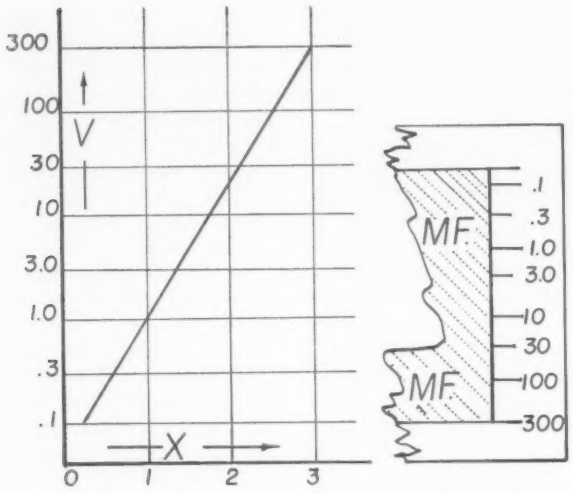

FIGURE 3.—Left: Exponential flow function (V) *vs.* height (X) of MF, corresponding to eight serial dilution steps. Right: corresponding flow (and deposit) scale on MF frame.

in those ranges of the membrane which were passed by water prior to clogging.

For the application of the molecular filter technique in concentrometric filtration, most sewages require dilution in spite of the wide range—as illustrated by the following example:

Assuming that a waste sample (for example, raw sewage) should be tested, where the estimated concentration of coliforms is about 2×10^6 per ml., but where, of course, the actual concentration could be substantially lower as well as higher. The operator could then take 500 ml. of tap water (because of negligible count) and introduce into it 5 ml. of a 10^{-4} dilution of the sample, corresponding altogether to a 10^{-6} solution on a milliliter basis, with which the container is filled, and of which 300 ml. subsequently would pass the MF. A pattern of coliforms (if

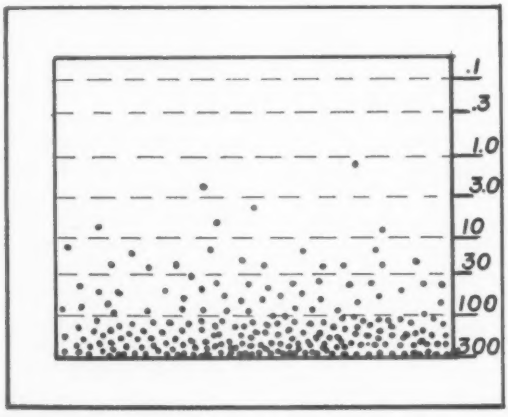

FIGURE 4.—Distribution of bacterial colonies for 60 org. per 100 ml., neglecting vertical statistical fluctuations, with corresponding flow scale on MF frame.

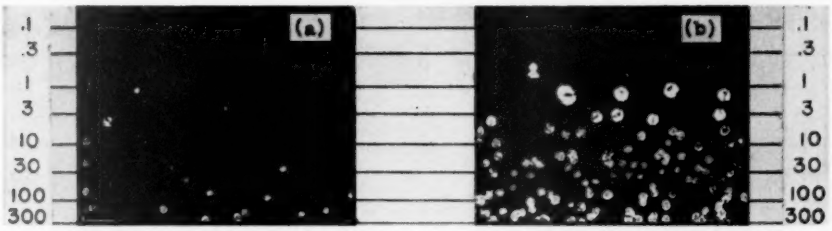

FIGURE 5.—Concentrometer record of untreated sewage: (a) dilution, 10^{-6}; count, 13 per 100 ml., equivalent to 10^7 per ml.; (b) dilution, 10^{-7}; count, 100 per 100 ml., equivalent to 10^7 per ml.

Endo nutrient schedule is used) will be obtained which resembles closely that of Figure 4, leaving, however, room for an accurate determination even if the count was 120 times higher than estimated (2.4×10^8 per ml.) or if it was 200 times smaller (namely, 1×10^6/ml.).

It is of interest to compare the indications obtainable with that of an MPN derived from serial dilution tubes. As a general rule (omitting involved statistical considerations), it can be expected that colonies above a certain scale mark (for example, 10 ml.) correspond to gas in corresponding (10-ml.) sample portions. If 1 or more colonies on the same MF lie also above the 1-ml. mark, it means that one or more parallel portions of the 1-ml. volume would carry gas as well.

The difference between an MPN determination and an MF indication on the concentrometer scale means, mainly, that under normal conditions of statistical distribution of the organisms the actual number of colonies contained in a given portion is determinable. In other words, the information is added as to how many colonies would have been contributing to the fermentation, if this volume had been diluted into a lactose broth tube. While this number adds a considerable degree of confidence over and above the MPN information, it still depends on the degree to which the portion that has passed the MF above the corresponding mark on the scale contained a quantity of bacteria representative of the concentration in the entire sample volume, and also to what extent the total sample volume is representative of the total water mass under investigation.

Figures 5a and 5b are representative of the concentrometric filtration of an untreated sewage sample in two different dilutions. It is evident that one sample carries about a 20 times higher concentration than the other, the original dilution being 10^{-7}, resulting in a total count of 4×10^9 per 100 ml. An analogous test of the same material after short exposure to partial chlorination is reproduced in Figure 6. Both samples were incubated under the same conditions on dehydrated nutrient Endo schedules (Isopor) and incubated for about 16 hr. at 37° C. It is noteworthy and probably of general interest that the colony growth in the untreated sewage sample is much more prolific than the colony development in the partially chlorinated sample, possibly indicative of certain inhibitory effects by the chlorination, which affected the growth rate in spite

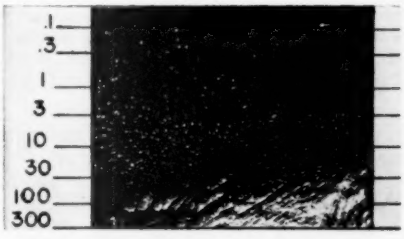

FIGURE 6.—Concentrometer record of partially chlorinated sewage: dilution, 10^{-4}; count, 100 per ml., equivalent to 10^6 per ml.

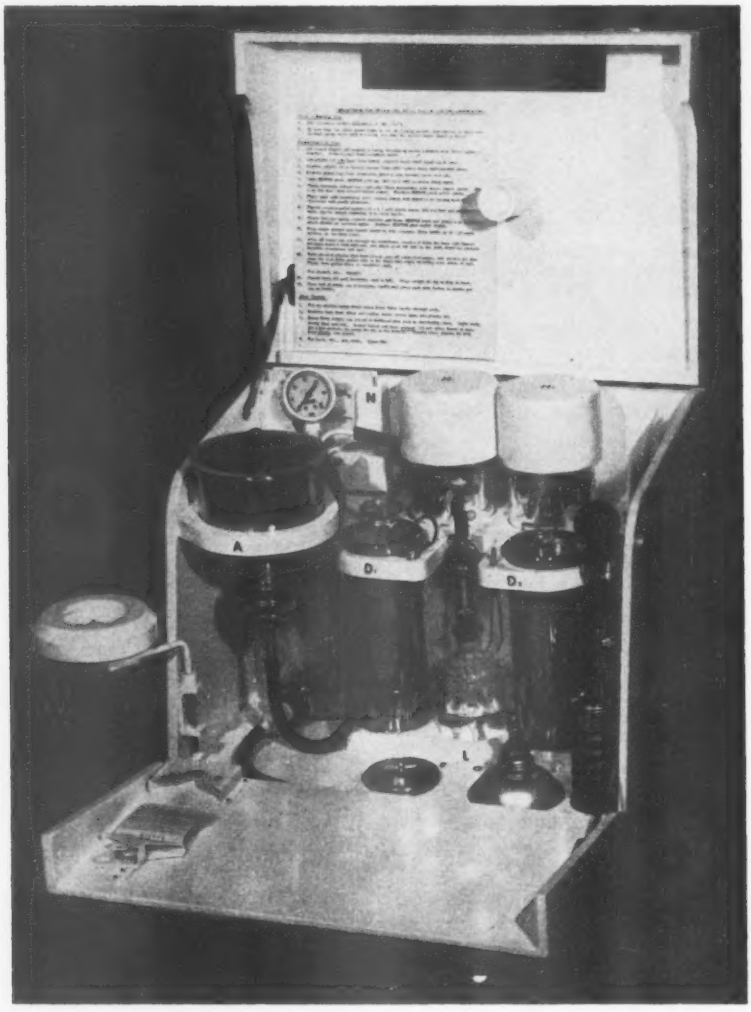

FIGURE 7.—Portable water laboratory containing: A, sterilizing MF holder with filter flask and pump (right); D_1, D_2, containers for 24 sterile Petri dishes; L, supply of sterile water with automatically metering pipette for rehydration of dehydrated nutrient pads; H_1, H_2, thermos incubator bottles for 24 tests; and various minor auxiliaries. Total bulk, 2 cu. ft.; weight, 33 lb. (Courtesy A G Chemical Co. and Leslie R. Burt Co.)

of identical nutritional an incubational conditions.

MF Tests under Field Conditions

One of the major advantages of the MF technique for bacteriological assays is the minimal requirement for laboratory equipment. Efforts have been extended, therefore, to design equipment which renders the performance of such tests entirely independent from laboratory facilities, inclusive of those of power, gas, etc. The main purpose is the avoidance of the neces-

sity for transporting water samples which often lose representative character in transit (unavoidable because most industrial facilities and smaller sewage plants have no bacteriological laboratory). The basic function of such a portable test laboratory (Figure 7) is briefly outlined, as it involves an apparently successful though radical departure from normal bacteriological procedures.

The filtration is performed as in the regular procedure, the vacuum being produced by means of a small hand-operated pump built into the laboratory case. The sterilization of the equipment is effected with formaldehyde (5), generated by incomplete combustion of a few ml. of methyl alcohol. Filtration and nutrition is effected with prefabricated, sterile, dehydrated, MF nutrient assemblies, opened only before each test series, and automatically rehydrated with pre-boiled (or MF-prefiltered) water.

The incubation procedure may be considered a new method, which, in order to be independent from any power supply, is performed in preheated water contained in thermos bottles, into which the Petri dishes containing the nutrient schedules and the MF's are inserted. Although the bottles represent satisfactory heat insulators, the temperature in the bottles and of the cultures drops from the initial temperature (100° to 104° F.) during the incubation period (12 to 16 hr.) to about 80° F. (depending upon the outside temperature). This results in an incubation on a slowly decreasing temperature: during the early growth stage (2 to 3 hr.) the temperature in the customary range of 35° to 37° C.; in later growth stages the temperature declines substantially and thus may be expected to retard the growth development. However, experience has proven that, particularly for coliforms and numerous other waterborne organisms on MF's, there is little, if any, difference noticeable between declining and constant incubation temperature. Actually it may be an advantage to retard growth development in the later stages of incubation in order to avoid premature confluence and lack of countability.

Although the method is very new and will require a thorough evaluation of its reliability, the experimental results so far available indicate its feasibility. If so, equipment of this type described would obviously be of considerable value, as it would render tests available at localities far distant from bacteriological laboratories.

In conclusion, it may be stated that the MF technique, in suitable modification for the specific needs of the bacteriological assay of sewage and other waste waters, as outlined, may prove an economic tool which facilitates surveys and frequent checks on treatment methods heretofore only possible at a major expense and without permanent record. On the other hand, a great deal of detailed experience will have to be collected in this field of application before a general code of specific rules can be given.

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TREATMENT PLANT PROGRESS IN CINCINNATI AREA

Plans to hasten the clean-up of the Ohio River and its tributaries were formulated at Cincinnati, Ohio, on October 6, when officials of river cities and villages from Pittsburgh, Pa., to Cairo, Ill., staged a Clean Water Rally. Concurrently, they dedicated Cincinnati's new $6,000,000 Little Miami sewage works; broke ground for another plant to cost $22,000,000; and inspected a third plant, half completed at Bromley, Ky., to cost $7,600,000.

The Little Miami plant is designed to handle 29 m.g.d.; the Millcreek plant is to handle 120 m.g.d. Two additional plants, both smaller than the Little Miami installation, are planned for completion in 1958. The Bromley plant, serving several Kentucky cities and villages across the river from Cincinnati, is to be placed in operation in 1954.

Participants in Cincinnati's pollution control program include seven cities and more than a score of villages. Residents of all the communities are paying a sewage service charge on their water bills to finance the program. Under the prevailing rates the average annual sewage service charge for a Cincinnati homeowner (based on water consumption) is about $6. Industrial sewage is graded, with producers of strong difficult wastes paying increasingly higher rates. For example, the annual bill for one large manufacturer exceeds $200,000. The entire Cincinnati program is expected to cost about $47,000,000.

ORGANIZATION AND MANAGEMENT CONTROL IN A SEWAGE TREATMENT PLANT*

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Of recent years a tendency to transfer the control of operating enterprises from engineering personnel to management trained personnel has been evident. Indeed, it has been stated (1) that: "A man with high administrative qualifications who has never been inside a steel or biscuit works may succeed. A man with all the knowledge of steel or biscuit making in the world but who lacks the requisite level of administrative knowledge and capacity will certainly fail." As long as engineering groups regard technical capacity and experience as superior qualifications for executive posts, the gradual transfer of control to administrative trained groups will inevitably occur. To answer the challenge, the engineer must study and apply the necessary administrative concepts that have been found just as self-evident in the theory of administration as the law of conservation of matter in science, or Hooke's law in enginering.

Part I. Organization

The first serious efforts to study the fundamentals of administration were made by Taylor in Britain, Fayol in France, and Mooney and Riley in the United States. It is significant that all were men of accomplishment in the field of business, Fayol being manager of a large French steel corporation, and Mooney a vice-president of General Motors. Their pioneering has been expanded and carried forward by others until it may be said that certain truths of administration are established beyond doubt.

Principles of Organization

The first and determining principle of organization is coordination—all acts of organization are directed towards securing coordination. In any relationship between men and groups of men two types of coordination are needed: one is vertical or "scaler" coordination; the other, horizontal or "cooperative" coordination. Coordination in the "scaler" or perpendicular sense involves authority and is the form in which leadership is needed to implement the necessary direction of any organized group. As a requisite corollary of leadership it is essential to delegate the proper amount of authority where necessary. The process of delegation, however, has only the purpose of coordinating the functions of the individual members of the group and is not a transfer of authority but, rather, a correlation of authority. The chain of correlated authority in any group runs from top to bottom.

The process of delegation of authority also involves the acceptance of responsibility for performance by the person who assumes the delegated duties. However, it must be remembered that responsibility cannot be delegated, for it is not a power but is the state of being accountable or answerable

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for the trust accorded one. Thus, since the manager or leader still has full responsibility, the person assuming certain delegated duties has assumed responsibilities which were created in the act of delegation. It is interesting to note (2) that ". . . the word 'leader' or the word 'lead' . . . has a very ancient meaning and comes from an Anglo-Saxon word that signifies 'carrying the load.'" The person in responsible charge—the leader—must carry the load and cannot hand part of the load to someone else.

Difference of Function

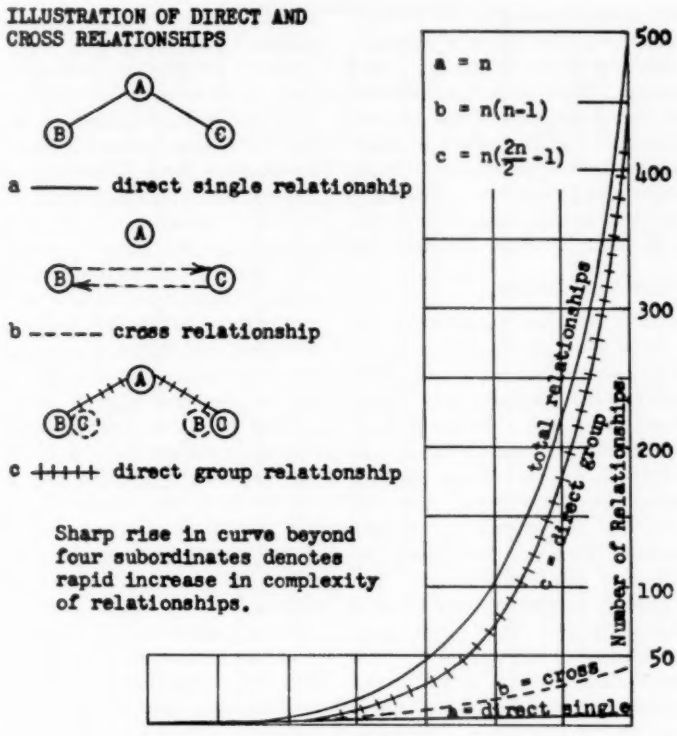
Any organization has groups whose functions are different; that is, a distinction between the kinds of duties of each group is possible. Similarly, persons comprising a group or function may have different tasks. A structure to interrelate the functions and, therefore, to accomplish coordination is absolutely necessary. In the structure each function and each task of each person must have a clear-cut line of authority, for no man can serve two masters. The clear definition of the area of responsibility of each function and the duties of each member of the structure is superimportant. Otherwise, the members will attempt to define their duties, with inevitable conflict with each other. Misunderstandings, frictions, and jealousies occur as a result; thus true coordination can only be obtained by functional definition.

Limit of Supervision

In the structure the span of control allotted to each supervisor should be restricted to four or five persons. It has long been known that one person can best supervise such a number. Figure 1 (3) shows mathematically why this is so. If a person supervises four people, the total number of combinations (possible interrelations of functions requiring supervision) amounts to 44. If a person supervises five people, the number of combinations is 100; for six people the number is 222. Thus, an increase in the number of functions supervised from four to six results in an increase of 178 in interrelations.

Line vs. *Staff Service*

In successful organizations, both religious and secular, that have stood the test of time, one always finds (a) the "line" of authority or command, and (b) the "staff" service of advice or counsel leading to the dissemination of knowledge. The line of authority represents vertical coordination; the service of advice represents horizontal coordination. True horizontal coordination is obtained through the universal service of knowledge and through an indoctrination into the common purpose for which the organization is founded. Although it is true that staff service is usually thought of as being at the top and serving management, it should instead extend throughout an entire organization. True service of knowledge is an equal necessity and sometimes of greater import than line authority. Such service is impossible through top contacts only, since each group striving towards a common purpose has important things to give not only the leader, but also each other. "This mutuality of things to be known extends upwards, downwards, and sideways, from the very top to the bottom of the organized structure" (4). In stressing the importance of the horizontal coordination, the following quotation is made: "It may well be that the system of organization, the structure of authority, is primarily important in coordination because it makes it easy to deal with the routine affairs and, thereby lessens the strain placed upon leadership so that it can thus devote itself more fully to the supreme task of developing consent, participation, loyalty, enthusiasm, and creative devotion" (5). The importance may be further stressed by noting that an idea or wave of feeling



a =	0	1	2	3	4	5	6	7
b =	0	0	2	6	12	20	30	42
c =	0	0	2	9	28	75	186	441
Total =	0	1	6	18	44	100	222	490

(Note: a = n = number of persons supervised)

FIGURE 1.—Span of control by Graicunas' theory (3).

may serve as the foundation of a coordination so strong that a concerted effort may be made by a group without a strong leader or without a real structure of command. Such things are often self-evident in any community where a spontaneous effort to improve the community occurs without any other driving force than the will of the people to accomplish a certain betterment.

The bare essentials, therefore, for an organization are: (a) strict definitions of functions and tasks, (b) relation of each function and task as outlined in a structure, (c) leadership through the proper delegated authority of each position, and (d) indoctrination in the common purpose of all those serving the organization.

Application of Principles

In illustrating application of principles to the rather general problem of

operating organizations in the field of waste disposal, the specific example of a large sewage treatment plant is presented. With some modification, however, the basic functional separations discussed can be applied to sewer maintenance, refuse collection, or similar operating organizations. The basic concepts can be applied with equal facility to large or small installations.

Breakdown by Function

Obviously the line function of the sewage treatment plant is the operation of the structures and equipment necessary for the processes comprising the treatment desired. The men whose tasks are to run the equipment are in this functional group. These are the men who start the pumps, turn the valves, charge the digesters, operate the vacuum filters, run the diesel engines, operate the chlorinators, etc. Sewage plant operators, incinerator plant operators, and diesel plant operators are typical of the group.

A second distinctive function is the maintenance and repair of equipment and structures at the plant. The basic duty of this group of employees is to keep the buildings and grounds neat and clean, to keep the equipment in good running condition, to repair and overhaul equipment as needed, to keep an orderly storeroom, etc. Personnel whose tasks comprise this function are machinists, mechanical repairmen, electricians, electrical mechanics, pipe fitters, painters, gardeners, janitors, and storeroom keepers.

Another function, clearly different from the first two, is the clerical force required. Timekeeping records, cost records, budget preparation, personnel records, the typing of letters, work orders, reports, etc., form a separate kind of duty.

A fourth separate function is the laboratory. In a sewage treatment plant routine tests are necessary for process control and evaluation of process efficiency. Tests are often necessary to satisfy State Board of Health requirements. The laboratory may conduct research for the improvement of treatment processes and assist the profession in the general increase of research and development work. Chemists, bacteriologists, and laboratory assistants are employed in this group.

The preparation of adequate reports concerning the plant's operation is a function of the engineering staff. No changes should be made in any piping, machinery installation, electrical connections, etc., without investigation by the engineering section. The engineering section is a logical focus for the control of plant instrumentation and for the investigation, development, and process control of treatment necessary at the site of the plant. The engineering section is charged with the constant development of cheaper ways of doing the same task, and conducts research for the improvement of processes and appurtenant equipment.

It can be seen that the duties of the first two functions—operation, and maintenance and repair—need more manpower than the other three functions of clerical, laboratory, and engineering. It can be assumed, moreover, that no further functional breakdown is necessary in the latter groups. However, the operations group, and the maintenance and repair group, may be divided into subfunctions.

Bearing in mind that the number of functions that can most advantageously be supervised is about four or five, the function of operation can be broken into four or five subfunctions. The subfunctions will vary from plant to plant, depending on the total number of processes installed. A logical grouping for a complete treatment plant is as follows: (a) sewage treatment, which includes preliminary, primary, and secondary treatment; (b) digestion and elutriation; (c) sludge dewatering, which includes vacuum filtration and sludge drying facilities; and (d) power generation and air gen-

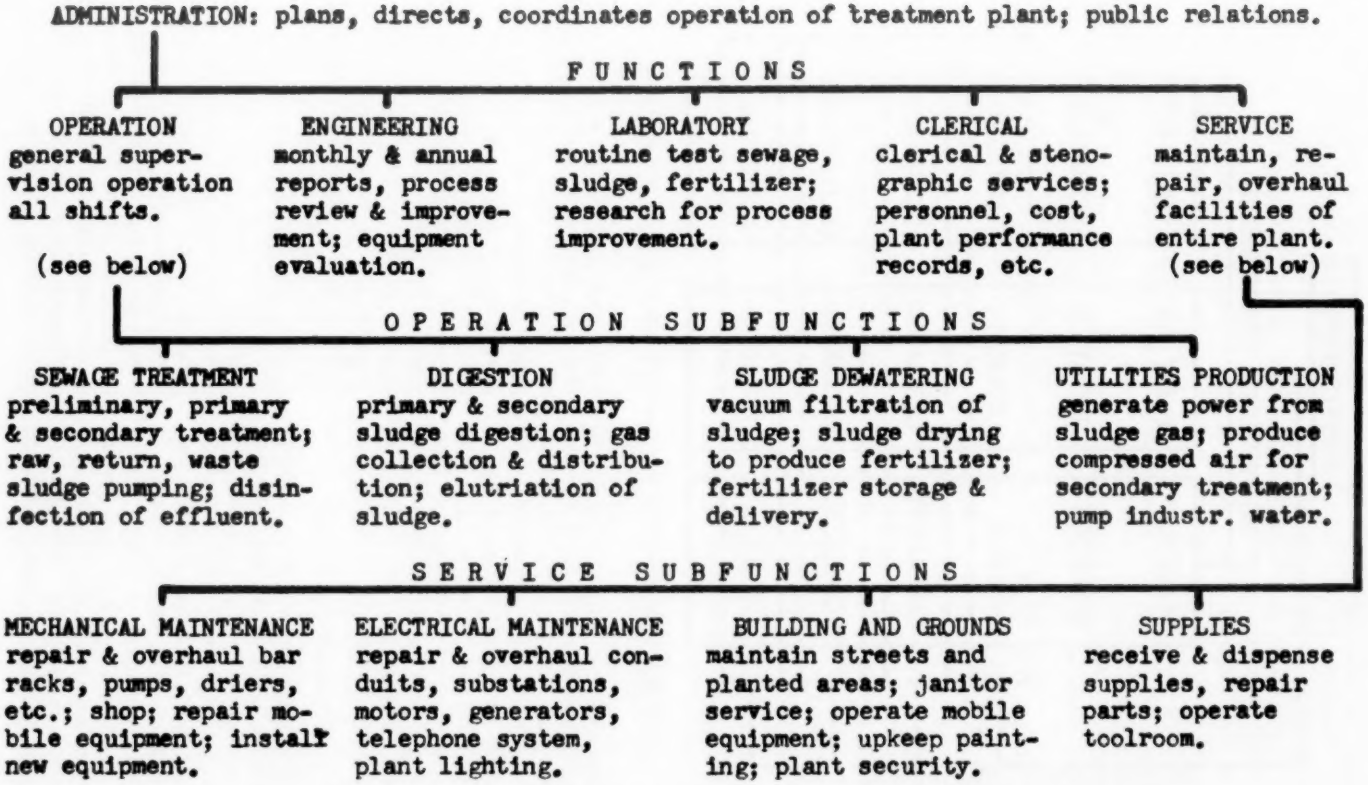

ADMINISTRATION: plans, directs, coordinates operation of treatment plant; public relations.
FUNCTIONS
OPERATION
general supervision operation all shifts.
(see below)
ENGINEERING
monthly & annual reports, process review & improvement; equipment evaluation.
LABORATORY
routine test sewage, sludge, fertilizer; research for process improvement.
CLERICAL
clerical & stenographic services; personnel, cost, plant performance records, etc.
SERVICE
maintain, repair, overhaul facilities of entire plant.
(see below)
OPERATION SUBFUNCTIONS
SEWAGE TREATMENT
preliminary, primary & secondary treatment; raw, return, waste sludge pumping; disinfection of effluent.
DIGESTION
primary & secondary sludge digestion; gas collection & distribution; elutriation of sludge.
SLUDGE DEWATERING
vacuum filtration of sludge; sludge drying to produce fertilizer; fertilizer storage & delivery.
UTILITIES PRODUCTION
generate power from sludge gas; produce compressed air for secondary treatment; pump industr. water.
SERVICE SUBFUNCTIONS
MECHANICAL MAINTENANCE
repair & overhaul bar racks, pumps, driers, etc.; shop; repair mobile equipment; install new equipment.
ELECTRICAL MAINTENANCE
repair & overhaul conduits, substations, motors, generators, telephone system, plant lighting.
BUILDING AND GROUNDS
maintain streets and planted areas; janitor service; operate mobile equipment; upkeep painting; plant security.
SUPPLIES
receive & dispense supplies, repair parts; operate toolroom.

FIGURE 2.—Functional distribution of tasks in a sewage treatment plant.

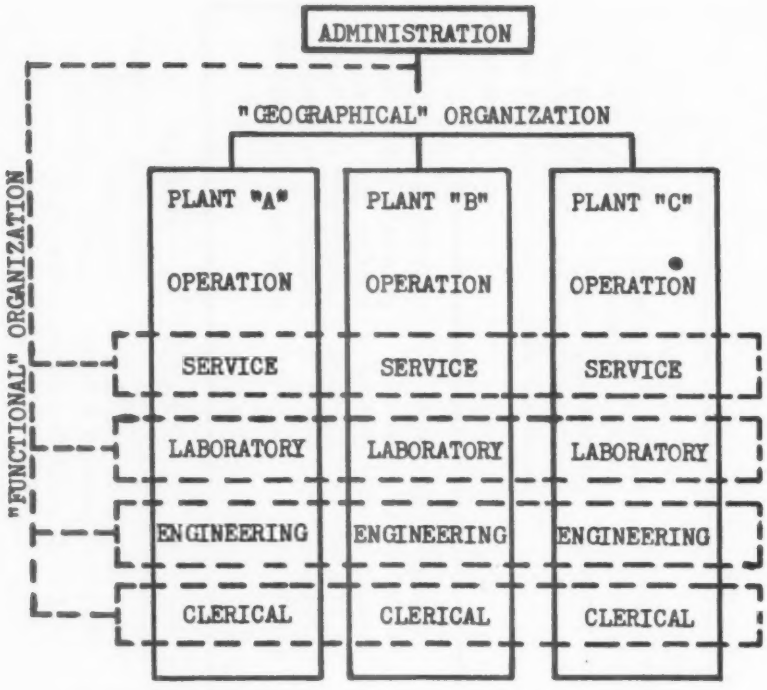


FIGURE 3.—Geographical and functional subdivisions in organization.

eration. Because the maintenance and repair group may also be of fair size in the plant, the following breakdown may be used: (a) mechanical maintenance; (b) electrical maintenance; (c) building and grounds maintenance; and (d) supplies. Thus, a clear separation of four maintenance subfunctions is made within the function of maintenance and repair of the plant.

Organization Structure

The organization structure is shown in Figure 2, which lists the important tasks of each function and subfunction. It is to be noted that this structure is given for single sewage treatment plant. If an organization is needed for several treatment plants, the evaluation of functional *versus* geographical organization, as shown in Figure 3, is necessary. For instance, suppose Plants A, B, and C each has a laboratory, but Plant A is larger and, therefore, has a chief chemist. Should the chemists in Plant B and C report to the chief chemist of Plant A (process division of work), or should they report to the superintendents of Plants B and C (geographical division of work)? The decision to be made rests on many factors, and must of necessity be solved not as an abstract case, but rather after all facets of the problem have been explored.

Other Necessary Factors

In the application of the concepts of administration, so far, the different functions found in a treatment plant have been discussed, and there has been indicated a structure to which the functions can be fitted. However, dependence cannot be placed upon an organization chart, or the listed delegation of duties, or the functional seg-

regation of work to operate a sewage treatment plant or any other organization.

Vitality, harmonious relation, and the will to work together must be instilled into the group. Certainly each man must be made to feel more than an automaton going through planned motions, for the Western World is not built on servile labor, but on the conception of the natural dignity of man, who has a responsiveness to "the feeling of accomplishment." Much has been written on morale, the psychology of group efforts, and the art of leadership. A few essential points in achieving horizontal coordination are as follows:

1. All employees should clearly understand the limitations of their functions so that they may proceed to do their work intelligently and well. The manager should understand thoroughly the network of his organization and should watch the areas where overlap and, therefore, jealously and friction can occur.

2. The possibility of modification of the structure of the organization. To suit the individual capacities of the section heads available and to take advantages of special aptitudes, certain subfunctions may be expanded.

3. The dissemination of knowledge. The average human being is a curious fellow; he enjoys knowing "what is going on," even though it has no direct bearing on his function. The general condition of the city's budget and of internal workings of other departments are of interest to the people in a sewage treatment plant; it is well to acquaint them with as many facts as can be had by management. Early release, to all persons, of information on research and development programs underway in the plant gives them a feeling of being part of the group and part of that research and development.

4. The encouragement of such groups as employees' safety groups, wherein the men from the various units meet to discuss over-all plant safety problems, and in-service training courses.

5. Personnel administration in its broadest sense is important, including the sympathetic treatment of hardship cases, promotion from within the group whenever possible, and general maintenance of conditions which serve as a foundation for a chance for a career service and the belief in the future of the enterprise.

Part II. Management Control

The elements of organization and the subdivision of tasks to be found in a sewage treatment plant have been discussed in Part I, together with the necessary structure to accomplish the job. Also, it has been stressed that horizontal coordination, the striving towards a common purpose, is necessary to any organization. The striving toward a common purpose must be directed, however to the correct purpose, and it is the basic function of management to see that the common purpose is the correct purpose. This is possible by the use of certain controls.

What Control Is

"Control" is defined by Webster as meaning, "to check or regulate; to exercise directing, guiding, or restraining power over." Control is not autocracy; control is the direction of energy into the proper channels, the guidance of personnel towards the common purpose. To properly control, reliable information must be at the fingertips of management. Accurate record keeping and proper accounting procedures are the only means of obtaining the necessary reliable information. It is beyond the scope of this paper to discuss accounting procedures; suffice it to say that they are necessary in some form. Actually, modern accounting is basically simple and straightforward, and depends mainly on the systematic accumulation of detail. Only by detailed

accounting can management know the operating results and costs of operation of each unit in a plant. It is to be stressed that the accounting detail required in a sewage treatment plant can be determined only by the treatment plant's management. The accountant can give management what it wants to know, but management must determine what it needs to know before a proper accounting system can be installed. Accounting must be considered as a service to management and not an end unto itself, but only through accounting's summation of the past can the future course be effectively plotted.

Necessary control in a sewage treatment plant falls into three phases—processes, personnel, and supplies. Obviously, to control manpower utilization and purchase of supplies, accurate records followed by summation of the data are needed.

Personnel Control Evaluation

Control or utilization of personnel can be adequately evaluated by the proper use of time cards. One basic determination in accounting for a man's time is, "What did he do"? Was he engaged in operating something? Was he engaged in maintaining something? Was he engaged in installing new equipment? A second major item is, "Where did he work"? Did he operate in the primary settling system or the digestion system? The first item gives his basic task; the second, the location of his task. Thus, each man each day accounts for his time spent by means of a function charge and an area charge. The systematic collection of time cards and accumulation of charges by modern accounting methods make it possible to determine man-hours and the cost of operation of each unit in the plant.

Basically, interest is centered in the costs of operation of the various units comprising the plant and a breakdown of costs of each unit to determine how much is spent for operation, for maintenance, and for new installations. A simplified system, using a function charge and an area charge, is outlined as follows:

Function Charge	Area Charge
20—Operations, labor	100—General operations
30—Operations, maintenance work, labor	200—Preliminary treatment
40—Upkeep maintenance, labor	300—Primary treatment
50—Repair, labor	400—Secondary treatment
60—Additions and expansions, labor	500—Digestion
80—Operating supplies	600—Filter, drier, and fertilizer storage
81—Repair parts	700—Power and blower
82—New equipment	800—Utilities
	900—Warehouse, shop and grounds

The list is largely self-explanatory. All operators engaged in routine operations use function 20. Thus, an operator in the primary treatment section uses function 20, area charge 300. However, an operator may from time to time perform work of a type more closely approximating maintenance and repair—that is, make minor repairs to chlorinators, or prepare some equipment for painting. All work performed by operators, other than routine operation, is placed in function 30. Function 40 is upkeep maintenance; janitorial work is in this category. Function 50 is repair; repair of a pump is illustrative. Function 60 is additions and expansion; work of this category does not mean major expansion of a plant, but items such as an installation of a better pump seal-water system, general minor new installations, and minor new process piping, etc.

The basic divisions on material costs might be as follows:

1. Operating supplies, such as chlorine, ferric chloride, janitor supplies, etc.
2. Repair parts, such as pump impellers, bearings, etc.
3. New equipment, such as a new truck, pump, or analytical balance.

Depending on the size of organization, each function charge and each area charge may be further expanded as illustrated by the following:

Function	Area
50—Repair	300—Primary treatment
51—Mechanical repair (pumps, etc.)	301—Pre-aeration
52—Electrical repair (motors, etc.)	302—Tube cleaning
53—Structure repair (tanks, etc.)	303—Primary sedimentation
54—Building repair	304—Raw sludge pumping

From the combinations given, it is possible to account for each man's time—for instance, a mechanic assigned to repair a raw sludge pump would enter function charge 51, area charge 304 on his time card. From the previous list, any parts needed would be charged against function charge 81, area charge 304.

If each person employed and all purchases made are charged properly, the information listed in Figure 4 is readily available. This information should be obtained monthly and any deviations from normal closely investigated. The summary of charges against any particular area and function provides a powerful tool to adequately control manpower utilization and proper expenditures for materials.

Personnel Utilization

Personnel utilization can be controlled by an adequate system of "work orders." Of course, throughout a sewage treatment plant there are many station posts; that is, positions which require a man regardless of the flow of sewage or fertilizer produced. For instance, in a given sewage treatment plant, an operator may be required to keep the primary settling system operating whether that unit is processing 25 or 225 m.g.d. of sewage. Also, each unit has certain routine repetitive tasks that are not subject to control by work order. For instance, the laboratory must test the plant effluent and processes throughout the plant daily for summation of the treatment obtained. However, over and above normal repetitive tasks there are investigations, changes of equipment, etc. Anything above and beyond the normal repetitive duties of each unit should be authorized by work order of the plant manager only. The work order may originate in the staff or line function wherein the work seems to be desirable, but it must be submitted to the plant manager for approval prior to the work being started.

Examination of procedures in progressive industrial concerns shows that maintenance and repair work is closely controlled. Of course, there is normal repetitive work, including preventive maintenance, for which an "annual work order" can be issued. Other work can be accomplished through the use of "maintenance work orders." To insure that adequate records are kept, no mechanic should be assigned repair of any equipment until he has been furnished an annual work order or maintenance work order for that particular work. Annual work orders should be issued only by the plant manager. Maintenance work orders may be issued to the mechanic by the maintenance foreman or superintendent up to a certain limited sum, generally in the order of $25 to $100 estimated labor and material charge. Beyond a certain amount, depending on the size of the plant, but in no case probably larger than $100, the approval of the plant manager should be required before the work is begun.

UNIT	COST OF OPERATION					
	LABOR			MATERIAL		
	Operation	Repair	Staff*	Operating Supplies	Repair Parts	New Equipment
Administration						
Preliminary Treatment						
Primary Treatment						
Secondary Treatment						
Digestion						
Sludge Disposal						
Power Generation						
General Services (grounds, storeroom, etc.)						
TOTAL						

*Staff functions are engineering; laboratory; clerical.

FIGURE 4.—Cost control summary sheet for sewage treatment plant operation.

Three basic reasons are evident for the control by management at this point, as follows:

1. The work actually may be unnecessary or improper, or already requested.
2. The work should be done at some other time in relation to a larger job already in the planning stage.
3. The work should be requested by another unit or staff function under whose authority the job really belongs.

Process Control

Process control may well be considered as two basic problems. The first is the day-to-day check on plant performance. To check on all factors involved in the processes on a daily basis is impossible. However, an examination of any unit will reveal a critical point of control, or two, in each unit. For instance, in an activated sludge system it may be the level of dissolved oxygen in the aerator effluent, or the sludge index; in a digestion system it may be the volatile acid content of the digesting sludge; in the filter plant it may be the proportion of ferric chloride required to obtain the proper yield of filter cake. It is important to find a point of control in each unit and to have that item reported to the plant manager daily with any deviations from regular performance noted thereon.

In addition to the foregoing, process control implies factual summation and economic evaluation of adjusting plant operations to the least cost for the given disposal site and is effected by the systematic collection of operating data, logs in the operating units, etc., together with laboratory testing, indicating the work being done. The collection of data should be followed by clerical summation, and then followed by engineering evaluation of the operating results. The engineering evaluation should be discussed with repre-

sentatives of the operating units, as well as laboratory personnel, for comments and findings. After such discussion, any recommended changes in processes should be forwarded to the plant manager. Changes in processes should be made only on authorization of the plant manager; in no event should they originate within a unit of the plant itself, inasmuch as dislocations of treatment in other units may result. Thus, through the integration of the "line" function of operation and "staff" functions of engineering and laboratory, each unit in the plant is coordinated towards the common purpose. Obviously, the point of control is the review of the engineering process recommendation by the plant manager prior to the issuance of the direct order to the unit concerned to make a process change.

To an engineer, the interesting part of sewage treatment usually is not the subject discussed in this paper. Instead he would rather pursue the study of the processes of sewage treatment, the study of laboratory research and development, the engineering evaluation of possible changes and adjustments, and, in general assist in technical developments in the field. Certainly, a plant manager should devote much of his time to studies of this nature.

As the plant manager, however, he has a deeper obligation; the obligation of insuring adequate performance of his plant with minimum expenditure of public funds. To do this requires sound administrative practice. And sound administrative practice and control will enable him to talk the language of the city manager or a city administrative officer, and assist in the allocation of the necessary funds to adequately operate his plant.

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SEWAGE TREATMENT FOR RESORT AREAS*

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Adequate sewage treatment is highly important for a resort area, which depends for its prosperity on being able to attract, year after year, a goodly number of visitors. By the term "adequate treatment" is meant a plant that is odorless, is unattractive to flies or other insects, gives maximum health protection, and eliminates objectionable stream pollution. A single case of typhoid will adversely affect patronage, so that proper disposal of sewage in a modern plant can be of great money value to a community. Conversely, the lack of modern sanitation will seriously limit the prosperity of a resort community.

Before going into the engineering phases of design relating to sewage treatment for a resort area, it would be well to discuss some of the factors that are probably little known, but which are often more difficult of solution. The problem of sewage disposal for Sullivan County (N. Y.) resort areas is not new, but has been with the resort owner always.

Until relatively recent years, the New York State Department of Health did not make inspections of individual resorts, but confined its work mainly to investigation of complaints. About 10 years ago, the Department instituted a program of making annual inspections of resort establishments. As pressure for adequate sewage disposal was exerted on the individual resort owners, many subsurface tile disposal installations were made by owners of the smaller hotels, whereas the larger hotels constructed sand filters, in some cases preceded by trickling filters.

With the continued growth of this section as a resort area, hotels, rooming houses, and bungalows were enlarged so that within some 5 years most of the original installations had been outgrown to the point of being nuisances. Enlargement was difficult and costly; in some cases there was not land enough available for additional treatment; operation was often unsatisfactory. As a result, resort owners began to realize that the problem of waste disposal was going to be a recurring, long-time, and difficult one, and that the best solution would lie in community action.

It is likely that many people think of this resort problem in terms of villages; but the big problem is not in the incorporated villages, but in the so-called rural areas where the town is the only form of local government. For the most part, the hotels, rooming houses, and bungalow colonies are well outside of incorporated areas. Often they are grouped around a lake or other feature of attraction for summer visitors. Therefore, if sewage treatment is to be provided for resort areas, it is necessary to start at the town level and create a legal community that can act for the people.

The laws of the State of New York provide a method under which a section of a town can form a water, sewer, or other district, and it is these laws that make it possible to solve the sewage disposal problem in a sanitary and economical manner. The procedure is

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as follows: Those interested in providing community sewage (or water) facilities state their case to the Town Board, which may engage an engineer. The bounds of the proposed district are determined and established, preliminary plans are made and an engineer's estimate of cost is prepared. A petition for the formation of the proposed district is then drawn up. This must be signed by more than 50 per cent of the resident property owners representing more than 50 per cent of the assessed valuation of the proposed district. After these requirements are met the petition is referred to the Town Board, which calls a public hearing on the proposal, and then either approves or disapproves the petition and the consequent establishment of the district. If it is approved by the Town Board, the petition then goes to the State Comptroller for his decision as to whether or not the people within the district can afford the burden of taxes they will have to pay. If the Comptroller approves, the Town Board establishes the district, which is thereafter under its jurisdiction.

Final plans are then authorized, bids are taken and the works constructed. The Town Board remains in control. The yearly budget, including interest, amortization, and operating costs, is assessed against the property owners. In the more thickly populated districts, the cost per year for sewage collection and disposal by this method is less than it is for individual disposal. Even in those districts where the cost is higher than for private disposal, there still remain three important factors in favor of the district plan, as follows:

1. Increasing the size of the resort establishment does not involve new problems and new capital expenditures for sewage disposal.

2. There are no restrictions on the use of a property due to a sewage disposal system being located on it.

3. There is considerable value in being able to advertise that the property is served by a public sewer system.

Engineering Data

From the engineering viewpoint, summer resort sewage treatment has many problems also. The plant must be designed for the heaviest organic loading that may occur over a short period, which is usually a holiday week-end, as well as for the heaviest volume of flow that is probable. Organic loading is usually heaviest during the period of the year when stream flow is near its lowest, so the plant must be capable of producing a very good effluent. In the area under discussion all streams are small and it is normal for the plant effluent to constitute at least 50 per cent of the summer flow of the stream into which it is discharged.

Finances also are a problem. The bond issue may not exceed 20 per cent of the average of the preceding three years assessed valuation. Operational and maintenance costs are highly important. The plant also must be designed to be suitable for operation under severe winter conditions, including sub-zero temperatures and deep snow, on a sewage flow that is likely to be one-tenth of the maximum summer flow.

Finally, there must be borne in mind the necessity for good year-around operation. A sewage treatment plant is no good unless it treats sewage. It cannot be operated in the summer and completely neglected the other 8 or 9 months of the year. So it is important to see that a good man is engaged on a year-around basis as an operator; that he is trained properly; and that he has the tools and equipment with which to work. This means an educational job on the Town Board or the Village Council. Wherever possible, the plants are designed for one-man operation, representing a considerable saving to the community. Even the

larger plants can be run by one man, although the volume of work in the summer months is such that he should have a helper.

Bearing in mind these primary elements—(a) the ability consistently to produce a good effluent, low in B.O.D.; (b) reasonable cost of construction; (c) simplicity and economy in operation; and (d) suitability for off-season cold-weather operation—the two-stage high-rate filter has been used for most of these small installations. The design is such that the two filters can be used in the winter as standard-rate trickling filters with the two units in parallel; and in the summer as two-stage high-rate filters with recirculation. A special advantage is that these units work very well, even when overloaded.

Design Data

Screens are provided for all plants. In the smaller ones, they are of the hand-cleaned type; the larger plants are provided with mechanically cleaned screens, usually of the type which also provide for grit removal. In the Sullivan County area grit removal is necessary and suitable equipment for this purpose ought to be installed. In the larger plants where the combined mechanical screen and grit removal equipment has been installed, space has been left for the later installation of special equipment for grit removal.

For primary clarifiers, either round or rectangular units are used. In the small plants, if conditions permit the use of a single tank, it is generally cheaper to use the circular construction. Detention periods of about 2 hr. are provided, based on design flow plus recirculation. Skimmers are always installed, with the collected material discharged to the sludge pumps.

The loading for high-rate filters is 2 lb. of applied B.O.D. per cubic yard of filter media based on the design loading of organic matter and the entire volume of filter media in both filters. Both filters are made the same size and are placed at the same elevation. Most filters are shallow—from 3 to 4.5 ft. deep. The stone is quite coarse (3-in. or larger) and is carefully selected and screened. The preferred method of placement is by clamshell, which is possible in the small filters usually required. Particular care is taken with the underdrain and ventilation system. Standard vitrified clay underdrain blocks are required, but vent risers at the periphery of the filter are not used nor are the drain lines extended through the wall. Experience has shown that by using good underdrains and filter media maximum results are obtained for the money spent.

A high recirculation ratio is not used. There is little advantage, in most cases, in using a ratio in excess of 0.5; the same ratio is used on both primary and secondary filters. For the larger plants, the axial flow of propeller type of pump is used for recirculation; and because the head at which it will operate can be determined within a few inches, and because this head is constant, efficiencies of 80 per cent or better can be obtained. For the smaller plants, a turbine type pump is used. During high-rate filter operation, recirculation pumps run continuously; there is no start and stop device on them—only a low-water and a high-water cutoff, with manual restarting. Recirculation design is usually as follows: The effluent from the primary filter goes to a small sump, from which the primary recirculation pump takes off a fixed amount and returns it to the primary clarifier, the remainder overflowing to the secondary recirculation sump. This overflow, supplemented as necessary by a draft from the secondary clarifier, is pumped to the secondary filter. Feed to the primary filter is by a dosing tank and siphon. For winter operation, the dosing tank and siphon apply the flow alternately to the two filters, without any recirculation.

Secondary settling tanks are de-

signed on the same basis as the primary tanks.

Sludge digestion capacity must be ample. In the large plants with heated digesters, the usual provision is in excess of 3 cu. ft. of digester capacity per person on the basis of the maximum expected summer population. After all, there is no great difference in initial cost between two 45-ft. and two 50-ft. digesters, but there can be a considerable difference in operation; and once a digester is built, it is impossible to enlarge it. In the small plants where heated digestion is not provided, digester capacity is 4 to 5 cu. ft. per person, based on the maximum summer population.

In the smaller plants, sludge beds of the open type are provided. In the area under discussion covered beds are fine, but they are still inoperative about five months out of the year, due to cold weather. In the larger plants, vacuum filters are provided for sludge dewatering. These units are arranged to be almost wholly automatic in operation. A belt conveyor loads directly from the filter into a truck. This retains the one-man operational feature. Sludge does not need to be handled, nor does the operator have to stand over the filter all of the time it is in operation. It takes about 45 min. to dewater a truckload, and during this time the operator can attend to other duties. Filters are large enough so that sludge dewatering can be handled in one day a week in the summer and much less often in the winter.

Operating results have been uniformly excellent, and final polishing of the effluent is not necessary; however, an effluent filter was installed at the Liberty plant 13 years ago and has given remarkable results, reducing the B.O.D. and suspended solids of the secondary clarifier effluent about 50 per cent, and producing a final effluent of the order of 10 to 12 p.p.m. The operating results cited are based on composites from 8 AM to 3 PM, because one man must run the plant and do the laboratory work also. B.O.D. tests are not run every day, but from time to time. Some results from typical plants for the July-August period of 1952 are given in Table I. In connection with this table, it should be noted that the Woodridge plant was converted from a seriously overloaded low-rate filter. Recirculation is provided from the effluent of the filter to the primary clarifiers and from the secondary clarifier to the dosing tank. Very good results have been obtained with this plant as modified.

The Kauneonga Lake plant also is a rebuilt plant. It formerly consisted of an Imhoff tank and a spray nozzle type trickling filter. New clarifiers and new filters were constructed, but the old gravel filter medium was used.

TABLE I.—Operating Results (July–August, 1952) of Typical Resort Area Sewage Treatment Plants; Composites from 8 AM to 3 PM

Plant	Flow (m.g.d.)	B.O.D. (p.p.m.)			Susp. Sol. (p.p.m.)	
		Raw Sewage	Sec. Clar. Effl.	Final Effl.	Raw Sewage	Final Effl.
Liberty, N. Y.	1.2	400	21	12	292	10
Monticello, N. Y.	1.2	210[1]	—	18[1]	140	11
Sackett Lake, N. Y.	0.3	230	—	14	128	25
Woodridge, N. Y.[3]	0.6	240	30[2]	—	—	—
Kauneonga Lake, N. Y.[3]	—	260	—	36	—	—

[1] Most tests have shown higher raw sewage B.O.D. with about the same effluent as given.
[2] Filter effluent; secondary clarifier out of service.
[3] See text for special notes.

The rounded aggregate does not appear to give as good results as does the cubical aggregate resulting from crushing stone.

Cost Data

The costs of the plants built during the past three years have averaged approximately $150,000 per million gallons of capacity. The Monticello plant, which has a normal capacity of 2 m.g.d., cost slightly more than $300,000, some of which was properly chargeable to the necessity for providing for heavy storm flows. The Woodridge plant, which involved mainly changing the old low-rate filter to a modified high-rate filter, cost less than $30,000. The Sackett Lake plant, 0.5-m.g.d. design capacity, cost about $75,000. The Kauneonga Lake rebuilding cost $62,000 for a capacity of 0.5 m.g.d. The Kiamesha Lake plant, now under construction, will cost about $100,000 for 0.6 m.g.d. capacity.

An attempt has been made to keep costs down by careful design. For instance, the primary and secondary clarifiers, the filters, and usually the digesters, are made of the same diameter so that the same forms can be used throughout. Although this is not possible with the larger plants, it has been followed with all of the small installations. Careful site examination avoids places where construction will be difficult and costly. Specifications are written to remove as much as possible of the risk to the contractor from unfavorable ground conditions. Wherever possible, pipes are used in place of channels. For the walls of the filters, tile blocks with hoop reinforcing have been used; where the filter is entirely below ground, a specially made concrete block is used. Both of these block walls are materially cheaper than the normal reinforced concrete containing wall.

Special care is taken to provide an attractive plant and to furnish good working conditions for the operator. A good office, a laboratory, and a toilet and shower room are standard. Money has also been saved by housing everything in a single building—office, laboratory, lavatory, sludge pumps, recirculation pumps, and, in the larger plants, the sludge dewatering equipment. The screens are not included in this building and ordinarily the sludge heating equipment is placed elsewhere, usually in a special building. In the larger plants, the office, lavatory, and laboratory are finished with tiled walls and good lighting is provided.

A neat and attractive plant with seeding and simple landscaping, and with a pleasant and comfortable office, is the best assurance that the plant will be well-operated and properly maintained. Relations with Village and Town officials, in general, have been exceedingly pleasant. After all, when they call on an engineer, they want and expect the work to be done promptly and properly. They want a degree of leadership, not long and complicated reports. Much more remains to be done in the resort section mentioned, but governmental units at all levels are aware of the needs of the area and it is believed that progress will continue to be made.

DISCUSSION

By Milton T. Hill

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In any discussion of municipal sewage treatment plants in resort areas, particularly in Sullivan County in New York State, the number of resorts such as hotels, bungalow colonies, rooming houses, lodging houses, and camps, together with the number of persons that can be accommodated, should be

of interest. The records of the State Department of Health show that during the past summer a total of 2,375 places were operated in Sullivan County with accommodations for approximately 170,000 persons. This total does not include a large number of places with accommodations for less than 10 persons or resorts served by both public water and sewer systems. It has been estimated that the population is increased to between 250,000 and 300,000 persons during the summer, a considerable increase over the normal population of 40,731 persons as given by the 1950 census.

Inspection of camps was undertaken on an annual basis about 20 years ago. This program was expanded in 1937 to include other types of resorts, such as hotels, rooming and boarding houses, and bungalow colonies, but it was not until about 1940 that sufficient personnel were made available to carry on a complete and satisfactory program. During the early years of the program the water supplies and sewage disposal systems at a good many of the properties were, in general, unsatisfactory; there were numerous outbreaks of illness, including typhoid fever, reported to and investigated by the local and state health departments. The improvements made in the past decade in these two major facilities, and in over-all sanitary conditions at resorts by the development of satisfactory public and private water supply systems and the construction of adequate sewer systems and sewage treatment works by individual resorts or by the towns and villages, have resulted in decreasing the incidence of illness to the point that during the summer of 1952 there was not a single outbreak reported in the county.

Although the local and state health departments can take some credit for the accomplishments, the major credit is due to the residents, both permanent and transient, to the local officials, and to the resort owners themselves, all of whom have become "sanitation conscious." In some proposed districts petitions by property owners requesting permission for the construction of public water and sewage systems are being held in abeyance by the State Comptroller's office pending further study because of the high cost of the proposed improvement as compared with the assessed valuation of the properties to be benefited.

Before 1935 there were only two public sewage treatment plants in Sullivan County. Both of these plants were subsequently entirely rebuilt in 1939 and in 1952 after they had become grossly overloaded. In the 5-year period between 1935 and 1940, sewers and sewage treatment works were constructed to serve seven sewer districts or villages, and one village completely rebuilt its existing plant. No construction was undertaken during the war years 1940–7, but since 1947 sewer systems and treatment works have been constructed by five villages and districts in areas not previously sewered, and four completely new plants have been constructed to replace older plants that had become overloaded due to the extension of sewers into new areas. The total capacity of the thirteen municipal sewage treatment plants in the county is approximately 7.0 m.g.d. In addition, one existing district has employed a consultant to study and prepare plans for sewer extensions into a large adjacent area and for the enlargement of the existing plant, plans for construction of sewers and treatment works are being prepared by engineers for a recently formed district, and residents of two other districts have signed petitions to have sewers and sewage treatment plants constructed.

It is of interest to note that six of the existing public sewage treatment plants, one large institutional plant, and one proposed public plant are located within a radius of 3 mi.; that twelve of the plants, including the in-

stitution plant and the proposed plant, are located within a radius of 6 mi.; and that included within these areas are large unsewered sections, which would be greatly benefited if public sewers were available. Such a concentration of public sewage treatment plants, with sewers serving only a small portion of the total area, may seem to be an indication of poor long-range planning: one or two properly located plants connected to trunk sewers might have provided sewage service to a greater area at the same or decreased cost. This contention is recognized as valid—if the phenomenal growth of the area and the need and desire for public sewers could have been predicted by any known method. Unfortunately, this could not be done, but it might well be taken as a lesson by other communities faced with a similar situation and where a reasonable forecast of future population growth can be made.

Two factors that have not been mentioned have a very definite bearing on the matter of public and private sewage disposal and treatment in the area under discussion. These are the generally unsatisfactory subsoil conditions and the use of most of the ponds and streams for recreational bathing purposes. Because of the prevalence of clay in the subsoil throughout most of the county, the disposal of sewage through the use of leaching pits or trenches is not practicable for the larger resorts. Existing systems of this type are gradually being replaced by trickling and sand filter installations or by connection to public systems. In January, 1953, there were approximately 125 private sand and 20 private trickling filter installations existing, under construction, or planned for construction prior to the opening of the 1953 resort season. Chlorination of the effluents from these works is generally required to protect bathing areas.

It has been indicated by Mr. Borden that sewage treatment plants require competent operation. Employment of the operator for a new plant during the construction period is very desirable and the State Health Department recommended that such a policy be followed whenever possible. Experience has shown that the operator so employed is better acquainted with the plant structures and equipment, has an increased interest in the satisfactory functioning of the plant, and is better able to correct conditions affecting operation.

The capacity criterion of 4 to 5 cu. ft. per person used as a basis of design by Mr. Borden for unheated digesters is felt to be more than ample, as the sewage flow for nine to ten months of the year is considerably below 50 per cent of the flow used as a basis of design for other structures of the plant.

AN INTERPRETATION OF THE B.O.D. TEST IN TERMS OF ENDOGENOUS RESPIRATION OF BACTERIA *

By Sam R. Hoover, Lenore Jasewicz, and Nandor Porges

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An explanation of the biochemical reactions that occur in the aerobic oxidation of milk wastes has been developed during the past three years in experimental studies at the Eastern Regional Research Laboratory. Two major phases were demonstrated—a rapid assimilation of the organic nutrients into cell material and a subsequent slow oxidation of these cells by their own (endogenous) respiration. Chemical equations for the growth reaction and for the endogenous respiration were established by chemical analysis and the rates of the two reactions were measured under a variety of conditions (5) (7).

The close analogy between the conditions of aerobic oxidation of milk waste and those of the B.O.D. test led to a study of the biochemical reactions that occur in the B.O.D. bottle. The B.O.D. test is paradoxical. It is the basis of all regulatory actions, and is used routinely in almost all control and research studies on sewage and industrial waste treatment. It has been the subject of a tremendous amount of research, yet no one appears to consider it adequately understood or well adapted to his own work.

The concept developed in this paper is supported by five lines of evidence. These are (a) theoretical argument, (b) rate of endogenous respiration of microorganisms, (c) rate of disappearance of substrate and oxygen in the B.O.D. test, (d) bacterial numbers in the B.O.D. test, and (e) determination of the rate of oxidation for 20 days.

Proposed Concept

The B.O.D. test consists of two biochemical reactions—first, the rapid growth of cells with assimilation of available nutrients into the cells, and second, the subsequent slow endogenous respiration of these cells. The first step is completed in a maximum of 24 hr.; often it is completed before the sample is introduced into the B.O.D. bottle. The second step is the prevailing reaction throughout the major portion of the test period. Whenever a monomolecular reaction rate with a velocity constant $k = 0.10$ is approximated in a B.O.D. test, the reaction is solely one of endogenous respiration. (The equations of monomolecular or first-order kinetics are well-known and need not be repeated here. The velocity constant in $\log_{10}$ units is k, in $\log_e = K$, in agreement with common usage.)

Theoretical Argument

Monomolecular reaction rates are observed whenever the amount of a given reaction occurring in unit time is directly proportional to the amount of reactant present. In general, two situations produce such a rate of reaction. The first is autocatalytic increase in bacterial numbers, which occurs for a

* Presented at a meeting of the Metropolitan Section; New York Sewage and Industrial Wastes Assn.; New York, N. Y.; March 18, 1953.

short time in the "logarithmic growth phase." After only a few hours, the medium becomes less suitable for the growth of the organisms because of lack of some essential nutrient or the accumulation of by-products, and the rate of growth decreases. Because of the extremely small amounts of nutrients in the B.O.D. bottle (< 5 p.p.m.), the logarithmic growth phase certainly cannot be maintained as long as 24 hr. To imply that the rate of oxidation in the B.O.D. test for 5 to 20 days is related to the monomolecular growth curve of bacteria is at variance with all existing knowledge of bacterial growth processes.

There is a second application of monomolecular reaction rates which can reasonably be applied to the B.O.D. test. Many enzymic processes can be adjusted to exhibit monomolecular kinetics over periods of days or weeks. The classical examples are the hydrolyses of sucrose, urea, synthetic peptides, and many other biochemical intermediates by their respective enzymes. Similarly, the oxidative enzymes of animal tissue and bacteria oxidize their substrates in proportion to the amount of substrate remaining and the ease with which the particular compound is attacked. Then endogenous respiration of bacteria is a noteworthy case. In the absence of available nutrients, the cells oxidize their own tissue slowly in order to obtain energy for maintenance. This reaction may approximate monomolecular kinetics for several days, but can be expected to fall off more rapidly than predicted from the equation as the cell is forced to oxidize its more stable components. Experimental evidence on this point is given in a later section of this paper.

Another general argument is based on the previous demonstration (4) that only three-eighths of the oxygen required for complete oxidation of lactose and casein by activated sludge is consumed during the growth of the bacteria. The remaining 62.5 per cent of the total oxygen required is consumed by the organisms in endogenous respiration. At least 60 per cent of the oxygen consumed in B.O.D. tests run for 10 to 20 days must be consumed by the organisms during the endogenous phase. In experiments conducted by many workers, in which B.O.D. tests were made on industrial wastes containing sugars, peptone, and other readily available substrates, this same rapid utilization of about 40 per cent of the theoretical oxygen requirement and a slow consumption of the remaining 60 per cent has been observed.

Rate of Endogenous Respiration of Microorganisms

The rate of oxygen utilization by the cells during endogenous respiration can be measured readily by manometric (4) and chemical methods (16). Simultaneous determination of the cell tissue present allows the rate of oxidation to be stated on an absolute basis. The term Q_{O_2} (oxidation quotient) is frequently used in biochemical research; it is the microliters of oxygen (μ l. O_2) used per milligram of cells per hour, calculated to standard conditions of temperature and pressure. The complete oxidation of 1 mg. of ash-free cell tissue requires 1.42 mg. O_2 or 993 μ l. O_2 (5). This latter derived value may be rounded off as 1,000 μ l. or 1 ml. of O_2 required to oxidize 1 mg. of cells completely. A Q_{O_2} of 10, therefore, is a rate of endogenous respiration which consumes 10/1,000, or 1 per cent, of the cell tissue per hour; similarly, a Q_{O_2} of 5 is 0.5 per cent per hour, etc. The same facts may be expressed on a basis of oxygen consumption; an endogenous Q_{O_2} of 10 is equivalent to a consumption in 1 hour of 1 per cent of the total oxygen requirement.

Many common organisms have endogenous Q_{O_2} values in the region of 10. Table I gives data from the literature.

TABLE I.—Endogenous Respiration of Common Microorganisms

Organism, Authors' Designation	Lit. Ref.	Measurement		Q_{O_2} (μl./mg./hr.)	Organism, Current Designation
		Temp. (° C.)	Time (hr.)		
B. pyocyaneus	(1)	22	2	12	*Pseudomonas aeruginosa*
B. prodigiosus	(1)	22	2	7	*Serratia marcescens*
B. fluorescens	(1)	22	2	16	*Pseudomonas fluorescens*
B. alcaligenes	(1)	22	2	7	*Alcaligenes faecalis*
B. proteus	(1)	22	2	5	*Proteus vulgaris*
B. cereus	(9)	25	2.5–4.5	25	*Bacillus cereus*
B. cereus	(8)	25	24	18–8[1]	—
B. coli	(1)	22	2	4	*Escherichia coli*
B. coli	(8)	25	2.5–4.5	8	—
Timothy grass bacillus	(1)	22	2	5	*Mycobacterium phlei*
B. subtilis	(1)	22	4	12	*Bacillus subtilis*
B. megatherium	(1)	22	2	6	*Bacillus megatherium*
Staph. aureus	(1)	22	2	10	*Micrococcus pyogenes* var. *aureus*
Sarcina aurantiaca	(1)	22	2	10	*Sarcina aurantiaca*
Saccharomyces cerevisiae	(19)	25	2	12[1]	*Saccharomyces cerevisiae*
Mycobacterium tuberculosis[2]	(11)	37.5	4	5	*Mycobacterium tuberculosis*

[1] Decreases exponentially with time.
[2] Starved for several days.

An attempt was made to find results obtained around 20° C., the temperature of the B.O.D. test. The endogenous Q_{O_2} of these organisms averages about 10, ranging from 4 to 25. The results of different workers are not strictly comparable, since the age of the culture, the time of starvation prior to making the measurements, and other variables affect the data. The excellent early studies of Callow (1), however, were conducted in such a manner that comparisons between organisms in the studies should be valid.

The "normal rate" of the B.O.D. reaction has been a matter of argument ever since the test was developed (18), but the value $k = 0.1$ in decimal logarithms, which equals $K = 0.23$ in natural logarithms, is the one most commonly used. This corresponds to an instantaneous rate of 23 per cent per day, or $23/24 = 0.96$ per cent per hr. Thus, an endogenous Q_{O_2} of 10 is just equal to the "normal rate" of the B.O.D. reaction.

The rate of respiration of growing organisms, on the other hand, is much faster, a Q_{O_2} of 100 to 200 being considered an average for growing organisms. This gives a ratio of growth respiration to endogenous respiration of at least 10. This high rate occurs only in B.O.D. determinations on industrial wastes containing readily available nutrients during the first day, when high k values are obtained (13).

Rate of Disappearance of Substrates and Oxygen in the B.O.D. Test

The B.O.D. test is made on a great variety of materials, some of which have already undergone microbial attack. The organic materials in sewage, for example, have in large part been assimilated by the organisms present, which may run as high as 400,000,000,000 per ml. Some industrial wastes have been partly converted to bacterial cell tissue by fermentation processes, but most of the processing wastes contain large amounts of free sugars and protein. Fresh dairy wastes are typical of the latter group, consisting entirely of soluble materials that comprise an excellent substrate for the growth of organisms. It is ob-

vious that the kinetics of the B.O.D. test on these wastes should be different. The ones high in readily available nutrients should show the rapid assimilation of soluble nutrients and the subsequent slow endogenous phase.

In previous experiments (4), the assimilation reaction was completed in 5 to 6 hr. In these manometric experiments, the cultures were agitated vigorously, and it was believed this agitation prevented diffusion from limiting the rate of assimilation. The question as to the rate of removal of soluble nutrients from the B.O.D. bottle remained open.

B.O.D. determinations of the usual type were made at 20° C. At appropriate intervals, the contents of replicate bottles were centrifuged at 15,000 r.p.m. for 30 min., the average relative centrifugal force being 23,000 g. Samples containing 230 ml. of the supernatant liquid were placed in Phillips beakers and covered with glass wool filters. The solutions were evaporated to dryness under forced draft at 106° C. The residue was suspended in 5 ml. of water, and determinations of oxygen consumed (O.C.) (17) were made in the same flask. An extensive series of control tests verified this procedure.

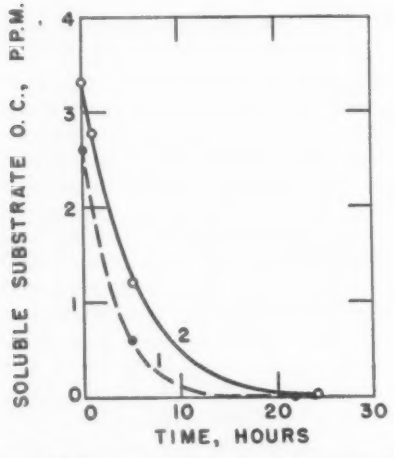

FIGURE 1.—Removal of soluble organic nutrients from the B.O.D. bottle.

Two experiments are recorded in Figure 1. In 5 hr. 77 per cent of the soluble substrate was removed in the first experiment and 64 per cent in the second. In all experiments, there was no determinable soluble substrate left after 24 hr. and at subsequent samplings. Thus, the rapid assimilation of the nutrients by the cells is demonstrated by direct analysis.

In Figure 2, additional confirmatory data obtained in the second run are plotted. The data on removal of B.O.D. and of total organic matter (O.C.) agreed rather well, but a slightly greater removal was shown by B.O.D. in the 5-day determinations. This latter result is in agreement with previous comparisons of the two methods used on aeration tank effluents (6). The outstanding result of this experiment is the rapid oxidation during the first day (assimilation) and the slower (endogenous) reaction thereafter.

The rate of oxidation per unit of cell solids can be calculated from the data (Table II). The cell weight used was the arithmetical mean of the initial and final cell weight for each period of time. This direct determination of the rate of oxidation in the B.O.D. bottle confirmed the proposed concept, for the Q_{O_2} was high (about 30) during the initial 5 hr., when the cell solids were increasing. Within 24 hr., the endogenous phase began, the Q_{O_2} of about 6 being maintained for the next 4 days.

The B.O.D. results in this series are in agreement with those of Norgaard

TABLE II.—Calculated Differential Rate of Oxidation (Q_{O_2}) in the B.O.D. Test Based on the Amount of Cell Solids Present

Time (hr.)	Cell Weight (p.p.m.)	Oxygen Cons. (p.p.m.)	Q_{O_2} (μl./mg./hr.)
0	0.85	—	—
5	2.21	0.33	30
24	2.05	1.37	18
48	1.70	1.75	5.9
120	1.42	2.70	5.9

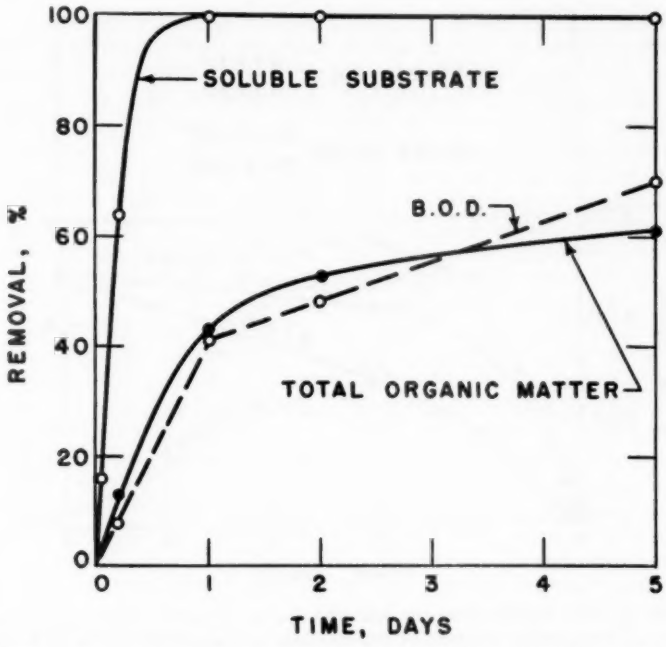

FIGURE 2.—Rate of removal of soluble organic nutrients compared with the rate of oxidation in the B.O.D. bottle.

(13), who observed a high ratio of the 1-day/5-day B.O.D. for industrial wastes, and utilized this ratio to characterize the biological treatability of industrial wastes.

Bacterial Numbers in the B.O.D. Test

Various workers have studied the numbers of viable organisms in the B.O.D. bottle, so only confirmatory experiments were conducted at this time. Muller (12), quoted by Theriault (20), found that the maximum count occurred on the second day and diminished rapidly thereafter. He also correlated the rapid rate of O_2 removal with the active multiplication of the cells; a 10-fold more rapid rate was calculated for growing cells than for resting cells. Many of the results on bacterial numbers obtained by more recent workers are complicated by a pronounced lag phase for a day or more, and interpretation of these results is difficult (10).

Two series of determinations of B.O.D. and bacterial counts were made (Figure 3). The inoculum or seed was an aerobic culture adapted to milk solids. In series A, the inoculum was deliberately made about as high as could be permitted in the B.O.D. test; in series B the inoculum was only about 5 per cent as great. All results were corrected for the O_2 consumption by the seed in control bottles. The B.O.D. results in series A were close to those discussed under "Rate of Disappearance of Substrates and Oxygen in the B.O.D. Test." The bacterial count approached 5×10^6 in 1 day and remained fairly constant for the ensuing 4 days. At the completion of the experiment in 20 days, the number of organisms had dropped to 200,000 per ml.

The results of Series B were in

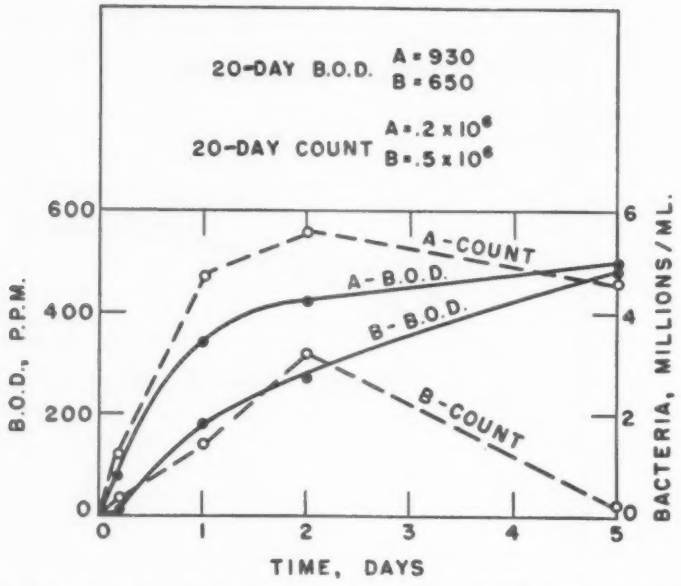

FIGURE 3.—Rate of oxidation and bacterial counts in B.O.D. bottle containing skim milk solids. The inoculum in series A was 0.33 mg. of cells per 300-ml. B.O.D. bottle; in series B, it was 0.016 mg. of cells per 300-ml. bottle.

closer agreement with those of Muller (12). There was a rather sharp maximum at 2 days, as well as an appreciable lag in the first few hours. The B.O.D. curve does not show the clear-cut separation into two phases, the slow initial portion producing a curve that approximates monomolecular kinetics fairly well.

The salient points shown by these tests are that the rapid bacterial growth process is virtually complete in the first day if optimum conditions are established, and second, with a small or an unadapted inoculum the lag phase may produce kinetics which, it is believed, fortuitously resemble those of a monomolecular reaction.

Determination of the Rate of Oxidation for 20 Days

For determination of the kinetics of oxidation on an absolute basis (that is, per unit of bacterial cells present), the aeration technique previously described was used (16). The required quantity of bacterial cells or sludge and substrate is aerated vigorously (1 volume per volume per minute) at 20° C. The CO_2 evolved is trapped and titrated. The oxygen consumption is calculated from the amount of oxygen in the CO_2 evolved, for it has been previously shown that the amount of CO_2 evolved is equal to the oxygen consumed when calculated on the molar basis. The amount of cell tissue present is calculated from the O.C. of the suspension before and after removal of the cells by centrifuging at a relative centrifugal force of 1,700 g. These O.C. values are plotted (Figure 4); thus the data are expressed wholly in terms of the O_2 used and the residual oxygen demand. (The O.C. value can be converted to cell weight by the factor 1.25 mg. O_2 = 1.00 mg. cell solids (2)(4). This factor may be slightly in error in the latter phases of the experiment, when the composition of

the cells is affected by the prolonged endogenous respiration. However, the factor would not be expected to change more than 10 per cent between the values of 1.12 for carbohydrate and 1.42 for protein.)

In the experiment plotted in Figure 4, duplicate series were set up, each of which contained 450 ml. of aerated sludge grown on synthetic dairy waste. The substrate, equivalent to 1,000 p.p.m. of skim milk solids, was added in 50 ml. of 0.06 M phosphate buffer (pH 6.9) to one series. The equivalent amount of buffer was added to the endogenous series. The initial composition is shown in Table III.

The CO_2 evolution was measured at the indicated times, and the data were corrected for the samples removed. The liquid volume lost by evaporation was restored before sampling. The initial pH was 7.0 ± 0.1; the final pH was 6.5 in both series.

The conversion of the soluble milk solids to bacterial cells was complete before the 24-hr. sampling time. At this time, 523 p.p.m. O.C. had been synthesized to cells, and the soluble O.C. was about equal to that of the endogenous series (Tables IV and V). The extremely high rate of oxidation in this initial period is evident from the slope of the line (Figure 4) and the Q_{O_2} of 72 (Table V). After this assimilation was complete, the rate fell to that of the endogenous series.

After 5 days, the oxygen consumed as measured by CO_2 evolution was within 10 per cent of that expected from the decrease in total O.C. (Table III). The oxygen balance at the conclusion of the experiment was also satisfactory, the total agreeing within 32 p.p.m. for the endogenous series and 20 p.p.m. for the series with substrate.

The kinetics of the two curves for oxygen demand are interesting because they explain certain anomalies in previous interpretations of the B.O.D.

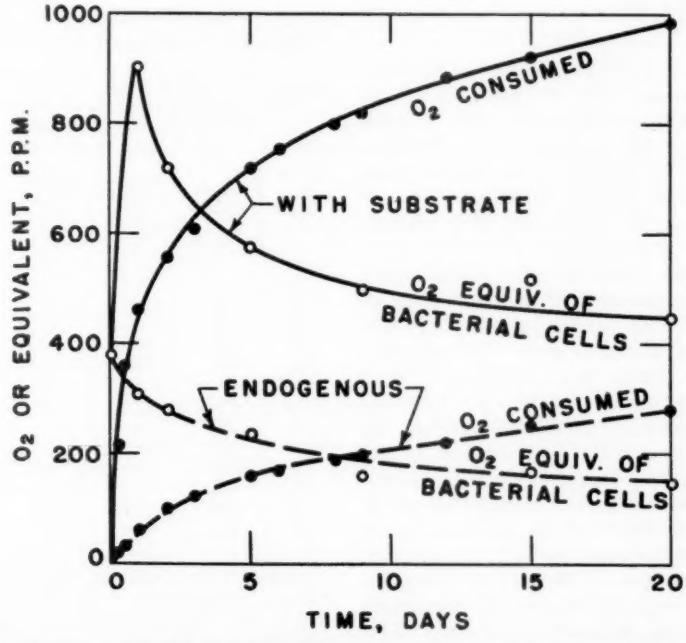

FIGURE 4.—Oxygen utilization and oxygen demand of bacterial cells during aeration.

TABLE III.—Oxygen Balance of Cell Respiration with and without Added Milk Solids as Substrate

Item	Endogenous	With Substrate
(a) Initial		
O.C., milk solids (p.p.m.)	—	1,055
O.C., sludge solids (p.p.m.)	382	382
O.C., sludge supernatant (p.p.m.)	46	46
O.C., total (p.p.m.)	428	1,483
(b) After 5 Days		
O.C., remaining, total (p.p.m.)	285	680
O_2 cons., by diff. (p.p.m.)	143	803
O_2 cons., by meas. (p.p.m.)	160	720
Discrepancy (%)	10	11
(c) After 20 Days		
O.C. remaining, total (p.p.m.)	180	514
O_2 cons., by diff. (p.p.m.)	248	969
O_2 cons., by meas. (p.p.m.)	280	988
Discrepancy (%)	11	2

test. (It must be noted that the oxygen demand here is only that of the carbonaceous oxidation; the oxygen used in the oxidation of nitrogen, which does occur in this system, is not evolved as CO_2 and therefore is not measured by the analytical procedure used.) A strict adherence to a monomolecular reaction rate requires that the amount oxidized per unit time be proportional to the amount of oxidizable material present. In the endogenous phase, this corresponds to a constant rate of oxidation per unit cell tissue present, or a constant Q_{O_2} (μ l. O_2/mg. cells/hr.) Inasmuch as the value of Q_{O_2} decreases during this period, the reaction cannot be truly monomolecular. The explanation of this fact is clear; the cell constituents differ in ease of oxidation, the more readily oxidized ones being consumed first in the battle for survival. The fed culture deviates even more widely

TABLE IV.—Endogenous Respiration of Aerator Sludge

Time (days) 1	Oxygen Cons. (p.p.m.) 2	Oxygen Equiv. of Cells (p.p.m.) 3	Oxygen Equiv. of Supernatant (p.p.m.) 4	Q_{O_2}[1] (μl./mg./hr.) 5
0	—	382	46	—
¼	19	—	—	7.5
½	31	—	—	5.3
1	62	309	66	6.8
2	101	280	52	4.8
3	126	—	—	3.4
5	158	235	50	2.5
6	169	—	—	1.7
8	186	—	—	1.6
9	195	161	89	1.9
12	222	—	—	1.8
15	247	169	15	1.5
20	280	150	30	1.7

[1] Differential rate calculated from Col. 1 and 2 and a smooth curve of the data in Col. 3 (Figure 4). The amount of cell tissue is calculated from the oxygen equivalent by the factor 1.25 mg. O_2 equiv. = 1.00 mg. cells.

from a constant Q_{O_2} for the same reason.

Neither of the two curves, then, is truly monomolecular. The Thomas plots (21) in Figure 5 are significant,

TABLE V.—Oxidation of 1,000 P.P.M. Skim Milk Solids (Oxygen Equivalent 1,050 P.P.M.) by Aerated Sludge

Time (days) 1	Oxygen Cons. (p.p.m.) 2	Oxygen Equiv. of Cells (p.p.m.) 3	Oxygen Equiv. of Supernatant (p.p.m.) 4	Q_{O_2}[1] (μl./mg./hr.) 5
0	—	382	1,101	—
¼	218	—	—	72
½	357	—	—	35
1	460	905	78	10
2	556	720	124	4.0
3	610	—	—	2.9
5	718	574	106	3.2
6	756	—	—	2.4
8	799	—	—	1.6
9	823	503	89	1.7
12	885	—	—	1.4
15	924	522	64	1.1
20	988	450	64	1.0

[1] Differential rate calculated from Col. 1 and 2 and a smooth curve of the data in Col. 3 (Figure 4). The amount of cell tissue is calculated from the oxygen equivalent by the factor 1.25 mg. O_2 equiv. = 1.00 mg. cells.

however. The curvilinear nature of the plot in the fed series is apparent throughout, and no approximation of a linear portion is evident. The plot for the endogenous series, however, appears to have a linear portion in the 1- to 6-day section of the plotted data. Nevertheless, close inspection of the data reveals that this portion is also curvilinear, but without the points at 8 to 12 days it is not possible to be certain of this deviation. The monomolecular constants of the linear portion are of interest also—the velocity constant $k = 0.17$ and the total load $L = 190$. Yet at 12 days the amount of oxygen used was 222 p.p.m., and the O.C. value of 382 p.p.m. initially present was twice the indicated value of L. If the amount oxidized were calculated on this true total load, the pseudomonomolecular rate would decrease to less than 0.1, just as the Q_{O_2} values of 7.5 to 2.5 require. It can be seen, therefore, that the apparent fit to the Thomas plot results from the false values of the two constants of the equation as obtained by this curve-fitting technique.

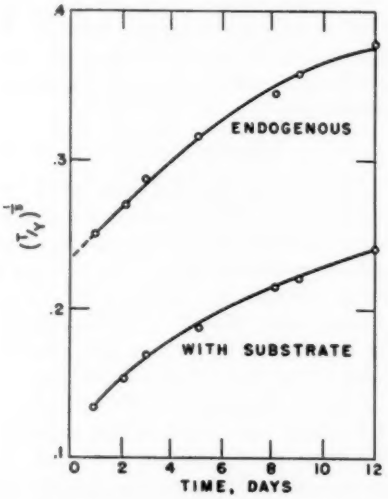

FIGURE 5.—Thomas plot of oxygen utilization.

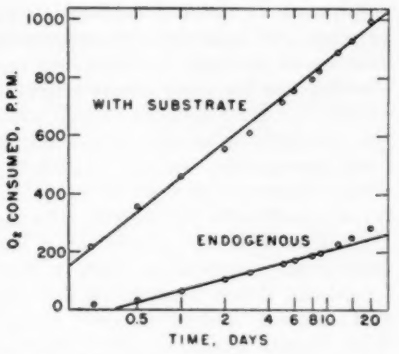

FIGURE 6.—Plot of log time *vs.* oxygen utilization.

The plot of amount of change *vs.* log time recently proposed by Orford and Ingram (14) as an empirical relation which fits much of the B.O.D. data, is also informative (Figure 6). The data of the endogenous series certainly fit this relationship for the period of 1 to 9 days, with appreciable discrepancy occurring at each end of the curve. A striking fit is shown by the data of the series with added substrate, for here the fit to the line is reasonably good from 0.25 to 20 days—almost 2 log cycles. This equation, despite its theoretical limitations, is apparently able to encompass the range of changing rates of oxidation observed. Thus the initial Q_{O_2} of 72 in the series with substrate decreases to 1.0 between 0.25 day and 15 to 20 days, a 72-fold decrease in 60 to 80 times as long a reaction period.

Such a log time relationship has been observed before in reaction kinetics of enzyme systems. The digestion of casein by the proteolytic enzyme papain fits this equation from 1 to more than 100 hr. (3). In the latter case, the existence of peptide bonds of varying ease of digestion was demonstrated. The analogy to the present oxidation system is evident, and is supported by the determined Q_{O_2} values.

It must not be concluded from the foregoing discussion that endogenous

respiration is never a monomolecular process. An apparent monomolecular decrease in the rate of endogenous respiration has been repeatedly observed (Table I). Such kinetics prevail while the available substrate of the cell is being consumed. In one noteworthy study Ingram (8) showed that *B. cereus* oxidizes its fat content, with the theoretical R.Q. of 0.7 and at a logarithmically decreasing rate. More frequently it has been shown that the carbohydrate content of cells is oxidized in such a manner (19). Most of the latter experiments have been conducted over a period of 2 to 6 hr.

It should be noted that the apparent monomolecular kinetics in these systems are obtained by measuring only the rate of oxygen uptake and that the constituent being oxidized at this rate is only a portion of the cell contents. If the rate were calculated on the basis of the total amount of oxidizable material present, which is the aim of the B.O.D. test, no such monomolecular kinetics would result. Consequently, use of the rate of oxygen uptake alone in calculating the amount of oxidizable material present is not a valid procedure. The previous discussion of the Thomas plot (21) of the endogenous series illustrates this point. In the work of Orford and Ingram (14), a similar adjustment of the total load, L, was required for even an approximate monomolecular reaction rate. Where the total amount present is of interest, as it is in the B.O.D. test, such an adjustment is clearly not permissible, as Orford and Ingram concluded.

On the basis of the results reported in this paper, a reassessment of the B.O.D. test seems to be required. It is clearly a dilution technique that has broad utility, just as dilution techniques are used in bacteriology. The rate of oxidation for the first day or two is difficult to interpret, for lag in the growth of organisms may obscure the high rate of oxidation during the few hours that growth is occurring at a logarithmic rate. The rate for subsequent days is primarily dependent on the particular bacteria that prevail in the mixture of seed culture and material being tested. The apparent monomolecular kinetics observed are not truly proportional to the amount of oxidizable material present, which fact constitutes a serious limitation of the B.O.D. test. Finally, when an apparent velocity constant, k, of about 0.1 is observed, the reaction occurring is primarily the endogenous respiration of the prevailing organisms.

Summary

The B.O.D. test consists of two biochemical reactions—first, the rapid growth of cells with assimilation of available nutrients into the cells, and second, the subsequent slow endogenous respiration of these cells. The first step is completed in a maximum of 24 hr.; often it is completed before the sample is introduced into the B.O.D. bottle. The second step is the prevailing reaction throughout the major portion of the test period. Whenever a monomolecular reaction rate with a velocity constant $k = 0.10$ is approximated in a B.O.D. test, the reaction is solely one of endogenous respiration.

Acknowledgment

The studies reported here were initiated as a result of reading the stimulating discussion of the B.O.D. test and its relationship to the activated sludge process by Phelps (15). The authors are pleased to acknowledge the value of his analysis in the development of the concept presented here.

John O. Hutchens, of the University of Chicago, first called to the authors' attention the logarithmic decline in the rate of endogenous respiration of many common organisms.

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BACTERIOLOGICAL STUDIES OF SLUDGE DIGESTION

II. Optimum pH at Which Sludge Digests When Inoculated with *Streptococcus diploidus*

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A series of small-scale laboratory tests, involving the inoculation of raw sewage sludge with *Streptococcus diploidus* (1), indicated that this organism was capable of decomposing this material. It was decided, therefore, to conduct additional experiments on a larger scale and determine the pH value at which this organism was most effective in digesting sludge.

Experimental Method

Approximately 7 gal. of raw sludge was collected from one of the primary settling tanks at the Back River sewage treatment works, serving Baltimore, Md. This material, which was derived from domestic sewage, contained on the dry solids basis approximately 30 per cent of a mixture of activated sludge, humus tank sludge, and sludge resulting from the flocculation with alum and subsequent settling of humus tank effluent. The sludge was disintegrated in a Waring blender and then separated into seven portions, each of which was put into a 5-l. Woulff bottle. To one portion, which contained 2,250 ml. and served as a control, 625 ml. of digested sludge was added. The ratio of raw dry volatile solids to digested dry volatile solids by weight in the mixture was 2.03 to 1 (Table I.). To each of the other six portions, each of which contained 3,000 ml., a 100-ml. saline solution containing *Streptococcus diploidus* was added. This suspension of bacteria was prepared by inoculating the organism in 5 l. of modified trypticase soy broth. After keeping the culture for 24 hr. at 35° ± 0.5° C., it was centrifuged for 1 hr. The supernatant was then decanted, and the concentrated cells were washed with a 0.85 per cent saline solution. After centrifuging the cells a second time, they were added to 1 l. of 0.85 per cent saline solution and stored overnight at 20° C. until they were used the following day.

The moisture and the volatile solids of the sludge in each of the seven bottles at the beginning of the digestion period are given in Table II. The contents of each bottle was thoroughly mixed and then kept at a temperature of 35° ± 0.5° C. The pH of the control was maintained at 6.8 and the pH values of the contents of the other six bottles were kept at 6.4, 6.8, 7.2, 7.6, 8.0, and 8.4. Concentrated hydrochloric acid and a solution containing calcium hydroxide were added to the bottles to maintain the desired pH values. The gas generated in each bottle was collected in 5-gal. carboys, which contained a displacement solution (2) adapted especially where gases containing CO_2 are collected and measured. The volumes of the displaced solution were measured at regular intervals. All gas volumes were corrected to 0° C. and 760 mm. of mer-

TABLE I.—Analysis and Quantities of Undigested and Digested Sludge Used in Control

Sludge	Weight (g.)	Moisture (%)	pH	Dry Solids		
				Total (g.)	Volatile	
					Weight (g.)	(%)
Undigested	2,250	94.8	5.3	117.00	84.94	72.6
Digested	625	76.3	6.4	148.13	41.91	28.3
Ratio, undigested to digested	3.6	—	—	0.79	2.03	—

cury. Analyses of the gas were made periodically. Moreover, the percentage of moisture, volatile solids, and the pH values of the sludges were determined regularly. The color, the odor, and the extent to which the sludge solids disintegrated were observed.

Results Obtained

The volumes of gas produced by the sludges are given in Figure 1. The greatest volume was generated by the sludge in the control bottle. Within 31 days the sludge had produced 402 ml. of gas per gram of fresh volatile solids. The reduction in these solids after 53 days was 54.8 per cent (Table II). The next largest volume of gas was produced by the sludge kept at a pH of 7.6. At the end of 53 days it produced 287 ml. of gas per gram of volatile solids, or approximately 72 per cent of the gas produced by the control. The volumes of gas generated by the sludges maintained at pH values of 6.8, 7.2, 8.0, and 8.4 were considerably less, varying from approximately 12 to 48 per cent of that produced by the control. No gas was produced by the sludge kept at a pH of 6.4.

The analysis of the gas is given in Table III. In general, the methane content of the gas generated by the sludges kept at pH values of 6.8, 7.2, and 7.6 varied from about 55 to 75 per cent, with the majority of the values exceeding 70 per cent. In the case of the sludges kept at pH values of 8.0 and 8.4, the methane content was considerably lower, ranging with two exceptions from approximately 40 to 54 per cent where the pH was 8.0, and from about 18 to 37 per cent where the pH was 8.4. In most instances where the percentage of methane was low, the percentage of carbon dioxide also was low. Small percentages of oxygen, which was undoubtedly a contaminant and which varied from 0.2 to 3.0 per cent, were found in the sludge gas.

Table II gives the percentages of moisture, volatile matter, and reduction in volatile matter in the sludges during the experiment. In every instance the percentage of moisture was greater at the end of the experiment than at the beginning. This increase was particularly pronounced in the case of the control, where the moisture increased from 89.4 to 90.9 per cent, and also in the case of the sludge maintained at a pH of 7.6, where the moisture increased from 94.9 to 96.3 per cent.

The reduction in volatile solids was most rapid in the control, amounting to 43.8 per cent in 31 days and 54.8 per cent in 53 days. Sludge at the Back River sewage plant is considered digested if the reduction in fresh volatile solids is about 45 to 50 per cent. The sludge kept at a pH of 6.8 had a volatile solids reduction of 45.9 per cent at the end of 53 days. This sludge, as judged not only by the volatile solids reduction, but also by its color, its odor, and the size of its disintegrated particles, was approaching a digested condition. The reduction of the

TABLE II.—Analyses of Sludge

Digestion Period (days)	Control[1] pH 6.8			Raw Sludge Inoculated with *Streptococcus diploidus*																
				pH 6.4			pH 6.8			pH 7.2			pH 7.6			pH 8.0			pH 8.4		
	Moisture (%)	Volatile		Moisture (%)	Volatile		Moisture (%)	Volatile		Moisture (%)	Volatile		Moisture (%)	Volatile		Moisture (%)	Volatile		Moisture (%)	Volatile	
		(%)[2]	Red.[3] (%)		(%)[2]	Red.[3] (%)		(%)[2]	Red.[3] (%)		(%)[2]	Red.[3] (%)		(%)[2]	Red.[3] (%)		(%)[2]	Red.[3] (%)		(%)[2]	Red.[3] (%)
0	89.4	44.8	—	95.0	70.1	—	94.8	68.6	—	96.3	69.5	—	94.9	68.6	—	94.6	65.8	—	94.8	69.0	—
7	89.1	37.3	40.1	95.4	65.9	17.6	95.1	65.0	15.0	95.2	63.5	23.7	95.2	64.4	17.1	95.3	60.4	20.7	95.2	63.9	20.5
17	89.1	36.8	42.4	95.2	65.0	20.8	95.0	64.2	17.9	95.3	61.8	29.0	95.2	58.4	35.8	94.9	61.4	17.3	94.7	57.3	39.7
21	90.8	37.3	40.2	95.6	60.4	34.8	95.5	56.2	41.3	95.3	61.5	29.9	95.4	59.7	32.2	95.1	55.3	30.1	94.8	57.0	40.4
31	91.0	36.5	43.8	95.5	60.3	35.2	95.5	60.8	29.5	95.5	60.7	32.2	95.4	59.8	31.9	95.3	55.8	34.4	95.8	59.4	34.3
36	90.9	37.9	37.2	95.4	61.6	31.5	95.7	60.9	28.7	95.8	59.6	35.3	95.7	59.8	31.9	95.5	61.1	18.7	95.0	58.9	35.6
42	91.1	36.2	45.1	95.8	60.4	34.8	95.9	55.7	43.6	96.0	56.7	42.5	95.8	52.4	49.6	95.0	51.8	44.2	95.1	57.4	39.5
49	90.9	36.1	45.6	95.7	61.0	33.0	95.8	55.2	43.6	96.2	55.5	45.3	96.2	51.5	51.4	94.9	54.9	36.7	94.9	50.1	54.9
53	90 9	34.0	54.8	95.9	59.0	38.6	95.8	54.6	45.9	96.4	54.0	48.5	96.3	48.8	56.4	95.0	50.5	47.0	95.1	56.5	41.7

[1] Mixture of 2.03 parts by weight of raw volatile solids to 1 part of digested volatile solids.
[2] Dry solids basis.
[3] Reduction of fresh volatile solids.

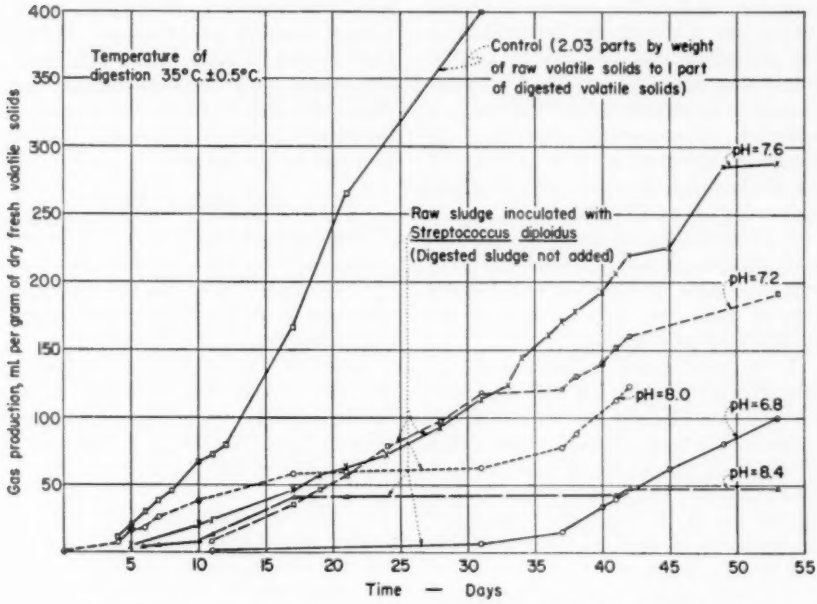

FIGURE 1.—Effect of pH on gas produced by raw sludge seeded with *Streptococcus diploidus*.

volatile matter in the sludges kept at pH values of 7.2, 7.6, and 8.0 was 48.5, 56.4, and 47.0 per cent, respectively, at the end of 53 days. All of these sludges were digested at the end of this time. The sludge maintained at a pH of 6.4 had a reduction in volatile solids of 38.6 per cent after 53 days. This sludge was only partially digested. Furthermore, the sludge kept at a pH of 8.4 was incompletely digested after 53 days as judged by the reduction in volatile solids.

Discussion and Conclusions

1. Raw sludge when seeded with *Streptococcus diploidus* and kept at a temperature of 35° ± 0.5° C. digested over a wide range of pH values.

2. The optimum pH value was 7.6. Forty-nine days were required to digest the sludge—a 58 per cent longer

TABLE III.—Analyses of Gas Produced by Sludge

Digestion Period (days)	Control[1] pH 6.8			Raw Sludge Inoculated with *Streptococcus diploidus*																
				pH 6.8			pH 7.2			pH 7.6			pH 8.0			pH 8.4				
	CH_4 (%)	CO_2 (%)	O_2 (%)	CH_4 (%)	CO_2 (%)	O_2 (%)	CH_4 (%)	CO_2 (%)	O_2 (%)	CH_4 (%)	CO_2 (%)	O_2 (%)	CH_4 (%)	CO_2 (%)	O_2 (%)	CH_4 (%)	CO_2 (%)	O_2 (%)		
27	70.4	24.0	0.8	—	—	—	59.8	14.4	1.6	—	—	—	—	—	—	—	—	—		
28	—	—	—	70.3	22.8	1.2	—	—	—	50.1	10.0	1.8	50.4	3.2	8.0	34.9	4.2	3.0		
31	70.2	29.0	0.8	73.6	26.0	0.4	69.5	27.8	0.4	73.5	22.4	0.4	54.0	22.4	2.6	22.2	5.2	1.2		
39	—	—	—	—	—	—	—	—	—	74.0	24.4	0.6	82.0	14.0	0.8	37.3	5.6	1.8		
40	57.4	27.0	1.0	72.3	24.8	1.0	76.0	23.6	0.6	—	—	—	—	—	—	—	—	—		
46	—	—	—	56.0	30.8	0.4	52.5	20.8	0.6	70.0	24.6	0.6	44.6	7.0	1.2	18.4	7.4	0.8		
47	55.0	25.2	0.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		
53	56.3	24.0	0.2	72.4	26.2	0.4	75.8	23.6	0.2	73.9	25.4	0.2	40.2	8.0	0.2	60.0	9.4	1.4		

[1] Mixture of 2.03 parts by weight of raw volatile solids to 1 part of digested volatile solids.

time than it took the control to digest. As the pH of the sludge deviated from 7.6, digestion was less rapid, smaller volumes of gas were produced, and the reduction in volatile solids was less pronounced. Considerable digestion was apparent, however, even in the case of the sludge kept at a pH of 6.4, where there was no production of gas.

3. Liquefaction of the sludge seeded with *Streptococcus diploidus* and kept at a pH value of 7.6 was considerably greater than the liquefaction of the sludge used as a control.

4. In general, the methane and carbon dioxide content of the gas produced by the sludges maintained at pH values of 8.0 and 8.4 was less than that of the gas produced by the sludges kept at lower pH values. When digesting sludge at the optimum pH value, the methane in the gas frequently exceeded 70 per cent.

5. It is believed that *Streptococcus diploidus* plays a significant role, both in liquefying and gasifying volatile sludge solids. To what extent it is a key organism in digesting sewage sludge remains to be seen. Further tests are to be made using this organism alone and in combination with other organisms isolated from actively digesting sludge to determine if digestion can be accelerated.

Acknowledgments

The Back River sewage treatment works, where the experiments were conducted, is under the direct supervision of R. J. Trautman and Paul L. Smith is plant superintendent.

Material assistance in conducting this experiment was rendered by the Baltimore City Health Department, of which Clinton L. Ewing is director of the Bureau of Laboratories.

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Industrial Wastes

GRAIN DISTILLERY FEEDS AND WASTES*

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At one time United States grain distilleries were very potent sources of stream pollution. Team research in the fields of chemistry, chemical engineering, biochemistry, nutrition, and marketing, along with capital investments of sizable magnitude, has proved the total recovery of stillage as various distillers feeds and their use as supplements in mixed livestock and poultry rations to be practical and profitable. If all the existing grain distilleries in the United States were currently operating, only 1 per cent of the total stillage from these plants would be wasted. If only the more efficient distilleries are considered, where total stillage recovery systems are in use—and these are the only ones currently being operated—the ultimate precentage of stillage wasted drops to practically zero. In these efficient plants there is no wastage or dumpage of stillage, all of it being routed to the recovery plant. These figures are based on a Distillers Feed Research Council survey, made in 1949, which showed also that of the 99 per cent of the stillage which is reclaimed, 14 per cent is fed to livestock in the wet form and 85 per cent enters the feed market as distillers dried feeds.

This accomplishment of reclamation of 99 per cent of the country's production of a material that was at one time largely wasted, and conversion of it into profitable products, was brought about by cooperative research efforts of grain distillers, feed mixers, and livestock and poultry research workers. From the pollution abatement viewpoint, the significance of the development of these reclamation processes and a profitable market for the recovered feeds is readily seen when it is noted that the B.O.D. of stillage is about 25,000 p.p.m. and that a plant wasting its stillage would have a population equivalent of approximately 50 per bushel of grain processed. The potential pollution load of an average distillery grinding 5,000 bu. per day, with no feed recovery, would amount to a population equivalent of around 250,000; that of a 20,000-bu. plant, such as the Hiram Walker plant in Peoria, Ill., a potential of 1,000,000.

Grain Beverage Alcohol Production Process

Figure 1 is a simplified flow-diagram of the basic process of the grain distilling industry. After preliminary grading and cleaning, the grain is milled, water is added to the grain meal, the suspension is cooked under steam pressure, and, with the addition of ground malted barley, a slurry called "mash" is formed. The enzymes of the barley convert the solubilized starch to grain sugars. To this cooled slurry, with the carbohydrates converted to the form of dissolved grain sugars, carefully pure cultured yeast is added. The yeast cells ferment the sugars to alcohol and carbon

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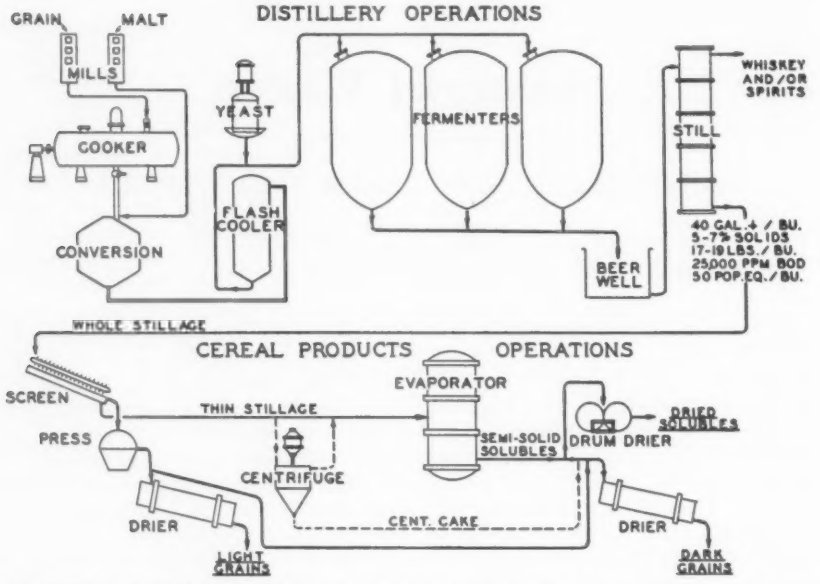

FIGURE 1.—Simplified flow diagram of grain beverage alcohol production process and feed recovery system.

dioxide, and, importantly, the yeast fermentation produces significant quantities of water-soluble vitamins. Upon completion of the fermentation, the slurry, now called "beer," is pumped from the fermenters to the stills for production of neutral grain spirits and whiskies of various types (bourbon, rye, etc.) and quantity of flavor (body). The de-alcoholized residue is known as "stillage." The various distillers feeds, fusel oil, and carbon dioxide are marketable by-products of this primary process of alcohol production from grain.

Stillage Reclamation Process

The volume of stillage, as pumped from the stills to the feed reclamation plant, amounts to about 40 gal. per bushel of grain processed, and each 40-gal. quantity carries about 18 lb. of solids. In other terms, the total solids content of stillage is about 6 per cent, of which about one-half is suspended solids and one-half is dissolved solids. The pH of stillage averages between 3.8 and 4.0. Whereas the starch of the grain has been converted to alcohol, the other components of the grain (protein, fat, and vitamins) remain in stillage in practically the original quantity, essentially unaltered in composition but concentrated three times due to removal of the starch. In addition, the yeast used has added vitamins and other animal nutrition factors.

Historically, the first of the reclamation procedures was to feed the whole stillage, supplemented with hay, to steers. It required one steer for each bushel of grind. The resultant manure created quite a nuisance and waste problem. Currently, wet stillage is fed only in rural areas.

The next development was to screen the stillage and dry the screenings. About 8 or 9 lb. of the 18 lb. of solids obtained from a bushel of grain can be recovered by efficient screens. The dried screenings enter the feed market today as "distillers grains," or, more specifically, "distillers light grains." However, half of the stillage solids re-

main dissolved in the stillage fraction that passes through the screens. This fraction is called "thin stillage." The vitamin and growth factors produced during fermentation, being water-soluble, pass through the screens. Although only a few evaporators were used in preprohibition days to concentrate the screened stillage, today most beverage distillers evaporate these solubles to a 25 to 40 per cent solids syrup and dry them with their screened grains to produce distillers dried grains containing solubles (dark grains). A number of distillers drum-dry part of their evaporated solubles to produce distillers dried solubles. This latter product was the result of post-repeal research by the Hiram Walker staff and was first placed on the market by this company in 1939. A large number of distillers now produce both dried grains containing solubles and dried solubles (see Figure 1).

The history and more complete descriptions of the various processes employed in processing grain to whiskey and alcohol and the recovery of the three types of distillers feeds have been published elsewhere (1) (4) (7) (9) (10) (11) (22) (23). The effect of using various grains and manufacturing processes on the chemical and vitamin content of distillers feeds has also been reported (1) (2) (3) (4) (19) (20) (22) (23). The role of these products in producing balanced poultry and livestock rations has been covered in a number of publications of the Distillers Feed Research Council, Inc., Cincinnati, Ohio, and elsewhere (1) (19) (20) (22) (23).

Special Uses for Distillers Solubles

Grain distillers screened stillage (2.5 to 3 per cent solids) and distillers dried solubles within the past few years have been found to be excellent media for a number of biological processes. The high soluble protein and vitamin content was first utilized as a yeast supplement by various distillers. The production of a malt replacement enzyme concentrate, fungal amylase, has been reported and the process has been used commercially to a limited extent (26). Dried distillers solubles are also being used in the media for commercial antibiotic production, mainly streptomycin (16) (17). Commercial production of a feed riboflavin (15,000 μ g. per gram) and vitamin B concentrate have been reported, as well as a process for the production of a feed vitamin B_{12} concentrate containing an antibiotic (5) (24). Both processes use screened stillage as the basic media. Distillers solubles and these refermented products contain not only appreciable quantities of known B-vitamins (Figure 2), but also other demonstrable, but as yet unidentified, growth, reproduction, and lactation factors (5) (13) (24).

Market for Distillers Feeds

The processes for manufacturing the various distillers feeds have now become satisfactorily efficient and the market has been sufficiently developed to make their production a profitable operation. Use as supplements in mixed feeds has kept pace with production except during exceptionally high production periods. During low production periods there is a great demand for distillers feeds, because replacements are usually in short supply and more costly. The modern distiller is constantly striving to get the best feed yield possible from the amount of grain entering the plant. There exists, therefore, a definite profit incentive for pollution abatement through total stillage reclamation.

Unit Process Pollution Load Studies

A modern distillery practicing complete stillage recovery produces certain airborn and liquid wastes characteristic of cooking, fermentation, distillation, evaporation, and drying processes. Although these wastes are far from the potent waste class of stillage, accurate definitions of the volume and

100 LBS. NET
CORN DISTILLERS' DRIED GRAINS WITH SOLUBLES
MANUFACTURED BY
HIRAM WALKER & SONS, INC.
PEORIA, ILL.
GUARANTEED ANALYSIS
Crude Protein (Min.) 25%
Crude Fat (Min.) 8%
Carbohydrates Nitrogen Free Extract (Max.) 10%
Nitrogen Free Extract (Min.) 38%
Member of
DISTILLERS FEED RESEARCH COUNCIL, INC.
WALKER'S STIMUFLAV
CORN DISTILLERS' DRIED SOLUBLES
HIRAM WALKER & SONS, INC., PEORIA, ILL.
100 LBS. NET
WALKER'S RIBO-15,000
A RIBOFLAVIN CONCENTRATE
Manufactured by
HIRAM WALKER & SONS, INC.
PEORIA, ILL.
GUARANTEED ANALYSIS
MINIMUM OF 15,000
MCG. RIBOFLAVIN PER GRAM
6,804 Mg. per LB.; 13,608 Gms. per TON
Crude Protein, Min. 33%
Crude Fat, Min. 3%
Crude Fibre, Max. 3%
Nitrogen Free Ext., Min. 30%
Moisture, Max. 8%
A grain vitamin concentrate produced by fermentation. Contains distillers solubles, distillers grains with added calcium carbonate to maintain the product free flowing.
FOR USE ONLY IN MANUFACTURING POULTRY AND LIVESTOCK FEEDS.
Member Of The Distillers Feed Research Council.
100 LBS. NET
WALKER'S RIBO-8,000
A Riboflavin Concentrate
MANUFACTURED BY
HIRAM WALKER & SONS, INC.
PEORIA, ILLINOIS
GUARANTEED ANALYSIS
MINIMUM OF 8,000
MCG. RIBOFLAVIN PER GRAM
3,629 Mg. per Lb.; 7,257 Gms. per Ton
CRUDE PROTEIN, MIN. 22%
CRUDE FAT, MIN. 3%
CRUDE FIBRE, MAX. 4%
NITROGEN FREE EXT., MIN. 25%
MOISTURE, MAX. 5%
A grain vitamin concentrate produced by fermentation. Contains distillers solubles, distillers grains with added calcium carbonate to maintain the product free flowing.
For use only in manufacturing poultry and livestock feeds.
Member of Distillers Feed Research Council

FIGURE 2.—Commercial feed supplement products produced from grain stillage.

B.O.D. of the various effluents have been found of pertinent value in studying the efficiency of the various unit processes. To supplement plant effluent surveys, and to identify and measure the exact sources of all residual wastes within the plant, Hiram Walker has for several years been conducting intraplant waste surveys whereby flow, B.O.D., and other analyses have been made of the waters leaving each unit process. The totals of the individual unit process surveys have been found to check very well with periodic week-long plant effluent surveys. These studies have led to recommendation of some equipment refinements that have squeezed a little better recovery yield

from certain units. In the case of other units the surveys have attested the fact that the recovery being obtained is at its economical best.

Table I summarizes the intra-plant survey averages for the Hiram Walker & Sons, Inc., Peoria plant. The wastes incidental to mashing and distilling operations are shown along with the feed recovery plant summary. Each of the values is based on many individual test periods. The tests were continued for each survey until the extent of operating variables was learned so that the waste data could be accepted as definitive of normal operation of the unit. The data of Table I are based on a 6-day mashing-distilling schedule and a production rate near the full capacity of the plant. Clean-

TABLE I.—Sources of Pollution Load from Modern Distillery Practicing Complete Stillage Recovery[1,2]

Source	Volume (gal.)[3]	Total Solids (lb.)[3]	B.O.D.[4]			Pop. Equiv.[3]
			(p.p.m.)	(lb.)[3]	(% of total)	
Cooking and fermenting						
Pressure cooker blowdown	3,671	11.5	124	3.8	0.7	22.4
Cooker blow vent stack drippings	24	0.7	500	0.1	0.02	0.6
Cooker vacuum aspirator trap	16,941	7.0	23	3.2	0.6	18.8
Flash cooler (*21*)	263,428	35.5	17	37.8	7.4	222.3
Flash cooler cleanup	314	9.2	2,025	5.3	1.0	31.2
Fermenter cleanup	3,388	3.2	421	11.9	2.3	70.0
Yeast tub cleanup	847	1.3	128	0.9	0.2	5.3
Total, cooking and fermenting	288,613	68.4	26	63.0	12.2	370.6
Distilling						
High wines water	3,097	1.6	256	6.6	1.3	38.8
Fusel oil wash water	3	0.8	89,000	2.2	0.4	13.0
Slop tester drain	48	1.4	1,500	0.6	0.1	3.5
Total, distilling	3,148	3.8	358	9.4	1.8	55.3
Feed recovery plant						
Hot well from triple evaporators (tail waters)	254,118	147.5	107	225.8	44.1	1,328.2
Hot well from finishing pan condensers	84,706	17.5	45	31.9	6.2	187.6
Fume chamber scrubber trap for vapors from drum dryers	25,412	18.6	275	58.2	11.4	342.4
Dust collector for dried grains dryers[5]	10,818	147.2	1,137	102.5	20.0	602.9
Scrubber trap for cyclone on dried grains cooling system	8,706	1.2	29	2.1	0.4	12.3
Scrubber trap for dried solubles airveyor cyclone	536	0.8	45	0.2	0.04	1.2
Equipment cleanup	350	110.0	2,057	6.0	1.2	35.3
Total, feed recovery plant	384,646	442.8	1,331	426.7	83.3	2,509.9
Powerhouse (powdered coal, wet ash, and fly ash recovery)						
Total, powerhouse	35,000	1,500	43	12.4	2.4	72.9
Grand total	711,407	2,015	86	511.5	99.7	3,008.7

[1] Data based on Hiram Walker & Sons plant at Peoria, Ill., operating at 100,000 bu. (mainly corn) per 6-day week, including 7th-day clean-up operations. Domestic wastes to city sanitary sewer. Well water (21 per cent of total) used in product processing; river water, 32° to 85° F. (79 per cent of total) used for all other purposes.

[2] All analyses by "Standard Methods" (25).

[3] Per 1,000 bushels mashed.

[4] B.O.D. data corrected for B.O.D. of river water where used.

[5] Recovery equipment being installed.

up wastes are included, making the totals equivalent to a 7-day week. The water-spray dust collectors in the feed recovery plant serve to eliminate a waste that would otherwise be a corrosive and dusty airborne waste. These water sprays are currently being converted to "thin stillage" sprays, with subsequent recovery of the collected solids. The largest population equivalent value is for the tail waters from the multi-effect evaporators. This waste has been thoroughly studied and found not to be an entrainment of solids, but essentially dissolved volatiles. The waste is dilute, but of comparatively high volume. Studies of distillery evaporator designs and the resulting wastes have been made by Pattee (18) and Davidson (11). They reported B.O.D. of the tail waters ranging from 10 to 3,200 p.p.m., with the more practical designs discharging at 400 to 600 p.p.m. B.O.D. Table I defines the Hiram Walker evaporator tailings in routine operations at 107 p.p.m.

The waste load of the Peoria plant, as shown in Table I, totals 3,008 population equivalent per 1,000 bu. mashed. Others have reported population equivalents of 3,500 (27) and 2,350 (14) per 1,000 bu. for plants under somewhat similar production rates and reclamation programs, but differing in production and recovery methods and equipment used. Another survey, where evaporator tailings and cooling waters are spray-tower cooled (and hence partially stabilized) and largely recirculated, reports population equivalent as low as 1,080 per 1,000 bu. mashed (11).

Periodic week-long studies made by Hiram Walker on its residual effluent waste to the Illinois River have shown it to possess a population equivalent of around 50,000 at normal operating rates. These data check well with the intra-plant source-potency studies summarized in Table I. With the flow in the Illinois River at Peoria running about 18,000 c.f.s., the residual waste from the plant adds less than 0.1 p.p.m. of B.O.D. to the river.

Water Usage and Effluent Volume

Traditionally, and for practical reasons, one of the most important natural resources sought in determining the location of a distillery is an abundant water supply. Water is needed to cool the mash to yeasting temperature, to provide condensing water for distillation, for boiler-water makeup, and, in the modern complete recovery distillery, to supply the vacuum condensers of the feed recovery plant. Hiram Walker has developed its Illinois River water resource to full usefulness and has pioneered some river water uses wholly new to the distilling industry (21). This has resulted in a considerable saving of the underground water supply, which is needed for mashing. At the present stage of this program, Hiram Walker's total effluent averages about 14 m.g.d. at near capacity, of which 79 per cent was originally river water and 21 per cent well water. Use of river water even when at summer temperatures, as a once-through coolant, has proved, in Peoria, to be more economical and efficient than partially closed systems using spray towers.

The use of river water has been extended to vacuum cooling of mash, to spray-type dust collectors in the feed plant, fly ash washers in the power plant to eliminate air pollution, and an ash washing system to aid the collection and disposal of power plant ashes. This program for full use of river water as a cooling water source during all months of the year accounts for the Hiram Walker effluent being more dilute and of larger volume on a per bushel basis than the discharge from certain other distilleries (11) (12) (14).

Final Effluent Treatment

The distilling industry provides an example of waste abatement through reclamation of the waste for profit. In the case of this industry, to dispose of the waste by conventional treatment, and thereby convert it to merely methane and fertilizer, would be a very wasteful procedure.

There remains the possible query as to the practicability of applying conventional sewage treatment methods to the remaining plant effluent waste. The precluding factors are that the waste is dilute, the effluent of the typical plant is of large volume, and the pollutants, almost completely in solution, are not amenable to concentration by sedimentation or flocculation. Costly distillery effluent treatment plants have been limited, therefore, to those plants where stabilization treatment was a positive necessity. Davidson (11) has summarized distillery waste treatment methods in use at four such plants. High-rate trickling filters loaded at 8 m.g.a.d., at a 4:1 recirculation rate, were reported to yield B.O.D. reductions of 93 per cent. This filtration rate loaded 6-ft. deep filters with 0.75 lb. of B.O.D. per cubic yard. Activated sludge treatment has been reported unsatisfactorily (11). Anaerobic treatment of this waste has been indicated satisfactory on laboratory scale (11). In 1932 Boruff and Buswell (6) reported successful studies on the 2- to 6-day thermophilic anaerobic digestion of concentrated stillage. Even better results should now be accomplished using the same authors' volatile acid control process (8). For a number of years the Peoria Sanitary District has digested, and further treated by activated sludge, some molasses and grain stillage with sanitary wastes (15).

Progress

The major progress so far in abatement of distillery wastes has been by elimination of dumpage of stillage and reclaiming it as various feed products, studying their role in mixed feeds, and promoting the results of such feeding trials and controlled demonstrations into profitable sales. This, it appears, remains the practical approach to maintaining and extending waste abatement accomplishments of this industry. By vigilant checking of the efficiency of the various unit processes within the distillery and the feed recovery plant, and comparison of overall yields of feed with the theoretical maximum for the amount of grain ground, the distiller will realize the maximum profit from processing of the grain and keep his final pollution load to a minimum. By continuing research on the animal feeding advantages of distillers feeds and promoting these results, a profitable market should be maintained. By extending these proven reclamation processes throughout the industry, the industry will move closer to the goal of complete elimination of stillage as a waste material.

Summary

Stillage is the most potent of all grain distillery wastes. Its complete recovery as distillers feeds or its use in the production of other products reduces the potential load of a grain distillery from 50 down to 1 to 3 population equivalent per bushel of grain ground.

The grain distilling industry is now equipped to recover 85 per cent of its potential stillage to distillers dried feeds; 14 per cent is fed wet, leaving only 1 per cent wasted.

A demand market for the various distillers dried feeds has been developed.

Final wastes from a modern distillery practicing complete feed recovery are high-volume wastes and, where disposal by dilution to bodies of water is not possible, are being treated separately and effectively on trickling filters.

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SOURCES OF B.O.D. IN BREWERY WASTES*

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The brewing of beer and ales as it is practiced in the United States consists essentially of four steps, as follows:

1. Brewhouse operations.
2. Fermentation.
3. Aging or lagering.
4. Packaging.

The basic raw materials used by the brewer are barley malt, corn grits, rice, hops, and water. Approximately 35 lb. of barley malt, 15 lb. of corn grits or rice, whichever adjunct is used, and 0.5 lb. of hops, are needed to produce one 31-gal. barrel of beer. Normally 10 to 16 bbl. of water are also consumed in the production of 1 bbl. of beer.

Brewhouse Operations

In the brewhouse, the grains are mixed with water, generally four or five parts of water with each part of ground grain, and then are mashed for 1 to 2 hr. In the mashing process, the starchy portions of the grains are conditioned so that they can be acted upon by the diastatic enzymes of the malt and converted to maltose sugars. It is these maltose sugars that are later fermented by the yeast. After the mashing of the grains with subsequent conversion of the starch to sugar and also considerable digestion of the proteins in the grain, the remaining grains are then separated from the liquor, which is now called wort.

The spent grains are removed, approximately 25 per cent of the original weight of grain being recovered as dried brewer's spent grains. This amounts to about 12.5 lb. of dried recovered grain per barrel of beer produced. The grains can be removed from the wort by large filter presses or by screening in cylindrical tanks that have perforated metal bottoms, commonly called lauter tubs. Both methods are in common usage and in either case the grains contain about 80 per cent moisture. It is common practice to reduce the moisture content to about 70 per cent by passing the wet grain through expellers. An average expeller liquor from a brewery using barley malt and corn grits has the following composition:

Total solids, as is	4 to 5%
Crude protein, dry	30%
Crude fat, dry	8%
Crude fiber, dry	5%
Ash, dry	3.5%
Nitrogen-free extract, dry	53.5%

The expeller liquor has high animal feed value and is much in demand for feeding to hogs and cattle. It can be sold "as is" if the brewery is adjacent to a farming area.

The spent grains, minus the expeller liquor, are now conveyed to the dryers, which are usually of the horizontal cylindrical rotary type with steam tubes as the drying surface. The grains are dried to approximately 8 per cent moisture and officially are designated as "dried brewer's grains." An average analysis of dried brewer's grains recovered from a brewery using barley malt and corn grits as the principal raw material is as follows:

Moisture	8%
Crude protein	26%
Crude fat	6%
Crude fiber	14%
Ash	4%
Nitrogen-free extract (by diff.)	42%

It should be noted that although the dried brewer's grains could possibly be

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a large source of B.O.D. material, they actually are a profitable by-product utilized as animal feed.

The clear wort which was separated from the grains now goes to the brew kettle, where hops are added and the mixture is boiled vigorously. The boiling serves the dual purpose of precipitating the heat coagulable proteins and sterilizing the wort. The hops are generally added to the boiling wort in several portions, both domestic and imported hops being used. Each individual brewmaster has his own particular hopping formula, just as each chef has his own individual formula for adding spices and flavor-producing materials.

A search of the literature reveals a variety of uses for spent hops. Nissen (1) suggested a number of uses, some of which are currently employed. The same author gives the following analysis for dried spent hops:

Moisture	8.04%
Protein	17.85%
Fat	4.90%
Fiber	27.77%
Ash	5.90%
Nitrogen-free extract	35.54%

Spent hops have been found to be good soil loosening agents provided they are plowed deeply underground. A compost of spent hops should have some fertilizer value. Wet hops are burned under the boiler in many instances, but their fuel value is low and in many cases they may be a hindrance rather than a help, due to their high moisture content. The spent hops have been dried and used as chicken litter, since they have moisture absorption properties and some germicidal value. Although some research work has been done (1) in this country on the addition of spent hops to brewer's grains, the idea has received but little acceptance and the various grain commissions have not been convinced that it is a desirable practice. The main objection of spent hops in feeds is their bitter taste and high fiber content. Brown (2) has reported the successful utilization of spent hops in feed for cattle and horses in England during World War II.

Fermentation and Aging

To continue with the brewing process: After removing the spent hops, the wort is then cooled to 40° to 50° F. and yeast is added. The fermentation is carried out in a cool building, commonly called a fermenterhouse, under sterile conditions and requires from 7 to 10 days, after which the yeast is allowed to settle and is removed. The beer thus produced is further cooled and goes to cold cellars for a storage or aging period from 1 to 2 months. A hundred years ago the cellars were just what the word implies, extensive underground areas where the beer vats were kept cold by the natural coolness of the earth. Today, however, the word "cellar" in a brewery most often refers to a multi-storied refrigerated building practically all above ground.

The removal of the excess yeast from the category of a brewery waste to that of a highly nutritious food, both animal and human, is almost a universal practice in breweries throughout the world. Approximately 0.5 lb. of dry yeast is recovered from each barrel of beer fermented. Most frequently this yeast is dried on some type of conventional roll dryer as it comes from the fermenter, without any further processing. It is used for animal feeding, as it contains a small quantity of enmeshed hop resins and is somewhat bitter in taste. A typical analysis of brewer's dried yeast is as follows:

Moisture	4.0%
Crude protein	47.0%
Crude fat	1.0%
Crude fiber	6.5%
Ash	6.0%
Thiamin	135 γ/g.
Riboflavin	40 γ/g.
Niacin	420 γ/g.
Pantothenic acid	80 γ/g.
Pyridoxine	40 γ/g.

It also contains chloine, inositol, biotin, and other vitamin B complex factors.

If the yeast is to be used for human consumption, the hop resins must first be removed, usually by mild alkaline treatment followed by water washing and drying. This yeast is known as debittered brewer's yeast and can be obtained at local drug stores in the form of compressed tablets or extract concentrates. In addition to being a source of readily assimilable organic nitrogen, brewer's yeast is rich in the vitamin B complex factors.

Packaging

After the 1- to 2-month aging period in the cellars, the stored beer is filtered and is then ready to be pumped to the packaging departments, where it is packaged in bottles, cans, and barrels. The traditional wooden barrels have practically all been replaced by either aluminum or stainless steel alloys. In 1952, the American public consumed 85,000,000 barrels of beer, of which 75 per cent was packaged in cans or bottles and 25 per cent in draught beer.

Waste Aspects

Mohlman (3) reported a population equivalent of 19 per barrel of beer produced in his survey of 28 breweries in the Chicago area. This over-all value is in agreement with data published by the Ohio River Committee under the auspices of the U. S. Public Health Service (4), and is also in close agreement with results found in collaborative studies with the Greater Peoria (Ill.) Sanitary District, to whose sewers the Peoria Heights brewery of the Pabst Brewing Co. is connected. Pertinent average data from this brewery, obtained in a 2-week survey period in 1949, are summarized as follows:

Average flow	284 gal.*
Pop. equiv.	12.4 *
5-day B.O.D.	890 p.p.m.
Protein	460 p.p.m.†
Reducing sugar	280 p.p.m.
Recovered material: ‡	
Volume	2.45 gal.*
Pop. equiv.	6.8 *
5-day B.O.D.	56,580 p.p.m.
Protein, dry basis	30%
Reducing sugar	5,000 p.p.m.

* Per barrel of beer produced.
† 28 per cent of total solids in protein.
‡ In addition to dried spent grain and yeast.

The volume of recovered material during the survey was obtained from gauged tanks and the flow of the waste to the sewers was determined by recording the head over 90° V-notched weirs. Samples were taken at regular intervals and stored in refrigerated containers. Automatic samplers, such as the Trebler sampler, have been used with some success, but it has been found that flow measurements obtained with head recorders are more reliable. Some work has been done on determining the waste potential of the various departments in the brewery, but it has been found difficult to sample the individual streams, as the underground piping is complicated and manholes are not generally to be found at the sampling location desired. Some data on the brewhouse operations are available, however, as it was possible to sample this water flow separately as far as B.O.D. producing material is concerned. Blowdown water from softening equipment and boilers made it impossible to accurately calculate the solids and flow from the brewhouse, but the blowdown waste contains no B.O.D. producing substances. It was found that of the 12.4 population equivalent per barrel of beer produced, about 4 of these could be from brewhouse operations.

There are a multitude of small wastes in a brewery which contribute to the over-all picture. It would be a

tremendous undertaking to evaluate all of them. Cleaning of equipment is normally accomplished by washing with either hot or cold water and neither alkaline materials nor synthetic detergents are used in daily routine cleaning operations. Barrel rinse water and rinse water from bottle cleaners contribute quite a volume, but are of lower B.O.D. than many of the other process wastes. Beer spillage is kept to a minimum in packaging operations and losses are quite small; nevertheless, a small amount does find its way to the sewer.

Treatment of brewery wastes is beyond the scope of this paper, but references should be made to two instances where breweries are pretreating their wastes. Bushee (5) has reported on a Houston brewery wastes treating system, and Schneider (6)(7) has discussed an Azusa, Calif. brewery. This West Coast brewery constructed a complete treating plant at the time the new brewery was built, due to the fact that the site selected was located in a small town whose treatment plant was already overloaded. This plant is actually a complete treatment and disposal plant and consists of a primary and secondary clarifier, two biological filters, a sludge digestion tank, three sludge drying beds, and four effluent spreading beds. Approximately 90 per cent B.O.D. reduction has been reported in the initial operation of this treatment plant. Mohlman (5) reports that although brewery wastes do add to the cost of sewage treatment, it is probably better and cheaper to handle these wastes with a large volume of sewage than to attempt to treat the wastes at the brewery. The 10 to 16 bbl. of water normally consumed in producing a barrel of beer means that the waste from a brewery becomes highly diluted and should not cause any serious difficulties in the operation of an average sewage treatment plant.

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TOXICITY OF COMBINATIONS OF CERTAIN INORGANIC COMPOUNDS TO *DAPHNIA MAGNA* STRAUS

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Within recent years much interest has centered upon the possible use of animals other than fish for toxicity tolerance measurements. The investigations have been conducted from the viewpoint of finding an animal that was (a) easily handled in the laboratory; (b) available at all times of the year; (c) neither too sensitive nor too resistant to chemicals; and (d) present in normal streams and of value to fish, either directly or indirectly.

Investigations by Anderson and others (2)(3)(4) show that the microcrustacean *Daphnia magna* Straus meets all of the requirements set forth, and much impetus has been gained from Anderson's work.

With these ideas in mind, a strain of *Daphnia magna* (obtained from Dr. Bertil G. Anderson, Department of Botany and Zoology, West Virginia University) was introduced into the authors' laboratory during August of 1949, and since that time a portion of the research work has been devoted to these animals.

This paper presents part of the research conducted on the daphnid and includes (a) an attempt to standardize the techniques for using *Daphnia magna* as a toxicity test animal, under the conditions used in this laboratory; and (b) a demonstration of the effects of combinations of inorganic compounds on the *Daphnia magna*.

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Material and Methods

In general, the culture and testing procedure employed has been that of Anderson *et al.* (4). The chief difference in the technique used for this work and that used by Anderson has been in the use of "standard reference water" (5) as the dilution medium in the toxicity tests and as culture media water.

The standard reference water used with the daphnids was the same as that used with fish (1)(6), except that the distilled water used with the daphnids was redistilled in a Pyrex glass still. Although it has been reported that the use of distilled water or "synthetic" water made from distilled water is impractical for culturing many invertebrates, including *Daphnia magna*, no difficulty has been encountered with standard reference water. Daphnids will not live in single-distilled water, but are easily maintained in good condition in reference water made with double-distilled water. Since the number of young per brood produced in the medium made with standard reference water is as high as that reported for "natural" (that is, lake or stream) water medium, indicating that the brood females are in equally good condition, it seems improbable that toxicity thresholds determined with reference water as the dilution medium would be lower than with natural water as the dilution medium. Theoretically, tests with reference water should be more readily reproduced, because nat-

ural waters may vary considerably from time to time.

Culture Method

Culture medium was prepared by mixing 5 g. of air-dried horse manure with 25 g. of dried sandy muck in 1 l. of standard reference water. The water used in the preparation of the standard reference water was first distilled in a Barnstead still and then redistilled in a Pyrex glass still with an internal nichrome heating element. The infusion was allowed to stand two or three days and then strained through silk bolting cloth. The filtrate was used after further standing of four to six days (4).

Daphnids for use in toxicity tests were cultured in 4-oz. wide-mouth bottles. One mature female was placed in each of a series of bottles filled with the culture medium. After four or five days, 1 mg. of yeast was added every other day to each bottle. The yeast was prepared by mixing 1 mg. of dried yeast per milliliter of reference water, and then employing 1 ml. of the resulting suspension.

Under these conditions, it was found that the females reproduced 30 young per brood, on the average, every two and one-half days. The young were removed every day to prevent depletion of the food supply, and were transferred to a stock tank to which occasional amounts of yeast were added.

A translucent viewing screen was used as an aid in making all observations; it was designed according to the method of Anderson (4), the dark-field illumination proving excellent for the necessary observations.

Testing Procedure

All young daphnids were removed from the culture bottles with a pipette 12 hr. prior to the beginning of the test. Thus, when animals were removed later for the tests they were not more than 12 hr. old. It has been shown (4) that the young daphnid is most susceptible to the toxic action of compounds at the time of molt; since the tests were conducted for 100 hr., it was thus assured that the animals would molt at least twice during the course of the experiments.

The daphnids were washed three times in reference water prior to being employed for the tests. This was done by transferring them from the culture bottles to a bottle containing reference water and allowing them to remain in the water for about 5 min.; this procedure was repeated three times.

The various test concentrations were prepared in 100-ml. quantities and put into 4-oz. bottles. Nine concentrations were made in a series of dilutions in geometrical progression. A tenth bottle was filled with reference water only and served as the control.

A preliminary experiment with the dilutions in fairly large steps, covering a wide range of concentrations, was conducted for each compound. In a few cases the range was not found in the first test, and another test was carried out, either raising or lowering the initial concentration as necessary. After having estimated the approximate threshold from the results of the preliminary experiment, three tests of each compound were conducted with a series of dilutions covering a narrower range of concentration.

In order to keep constant the relative concentration of each compound present in a given bottle of the tests involving combinations of compounds, the starting concentration was determined by multiplying the toxicity threshold concentration of the single compound by 1.78. Since the dilution sequence was in powers of 1.33, this placed the single compound threshold concentration in bottle No. 3.

Eleven observations were made during the 100-hr. period, the observations being made at intervals in geometrical progression in powers of 1.99. The number of young alive in each bottle at the time of observation was recorded.

Ten animals were employed for each concentration. All tests were conducted at a temperature of 23 ±1° C.

Chemicals Tested

Five inorganic sodium salts were tested singly, in combinations of two, and in combinations of three. The salts tested were sodium bisulfite, sodium carbonate, sodium chromate, sodium silicate, and sodium sulfate. All possible combinations were tested, giving a total of 25 different test solutions.

Calculation of the 100-Hr. Toxicity Threshold

The toxicity threshold is defined as that concentration which immobilizes 50 per cent of the animals in a given period of time. Thus, the 100-hr. toxicity threshold is that concentration which will immobilize 50 per cent of the animals in 100 hr.

The toxicity thresholds were calculated according to the method of Anderson (4) making use of the formula

$$\log c_1 - (a - 1)\log b = \log c_a$$

in which c_1 is the concentration of the compound in bottle No. 1 (that is, the highest concentration), a is the threshold concentration in terms of bottle number, b is the dilution factor (1.33 in all tests reported in this paper), and c_a is the concentration of the test material in bottle number a (that is, the threshold concentration).

Results and Discussion

The 100-hr. toxicity thresholds of the compounds tested are given in Tables I, II, and III. All results are the average of the three tests conducted on each combination and are expressed in parts per million.

Examination of the data shows that the thresholds are lower for the compounds when tested in combinations of two than for the single compounds, with the exception of sodium bisulfite and sodium silicate.

The 100-hr. toxicity thresholds of the compounds tested in combinations of three are lower than the combinations of two or for the single compounds, with the exception of sodium bisulfite with sodium silicate and so-

TABLE I.—100-Hr. Toxicity Thresholds of Five Inorganic Sodium Salts for *Daphnia magna* When Tested Singly

Compounds Tested	Threshold pH	100-Hr. Toxicity Threshold[1] (p.p.m.)
Sodium bisulfite	7.3	102
Sodium carbonate	9.5	524
Sodium chromate	7.8	0.42
Sodium silicate	9.1	247
Sodium sulfate	7.7	4,547

[1] Average of three tests.

TABLE II.—100-Hr. Toxicity Thresholds of Five Inorganic Sodium Salts for *Daphnia magna* When Tested in Combinations of Two

Compounds Tested	Threshold pH	100-Hr. Toxicity Threshold[1] (p.p.m.)
Sodium bisulfite Sodium carbonate	9.2	85 436
Sodium bisulfite Sodium chromate	7.3	70 0.286
Sodium bisulfite Sodium silicate	7.5	177 427
Sodium bisulfite Sodium sulfate	7.5	82 3,642
Sodium carbonate Sodium chromate	9.3	408 0.33
Sodium carbonate Sodium silicate	9.3	180 85
Sodium carbonate Sodium sulfate	9.2	221 1,918
Sodium chromate Sodium silicate	8.7	0.159 93
Sodium chromate Sodium sulfate	7.9	0.276 2,984
Sodium silicate Sodium sulfate	9.0	158 2,899

[1] Average of three tests.

TABLE III.—100-Hr. Toxicity Thresholds of Five Inorganic Sodium Salts for *Daphnia magna* When Tested in Combinations of Three

Compounds Tested	Threshold pH	100-Hr. Toxicity Threshold[1] (p.p.m.)
Sodium bisulfite		87
Sodium carbonate	9.3	440
Sodium chromate		0.35
Sodium bisulfite		38
Sodium carbonate	8.8	194
Sodium silicate		92
Sodium bisulfite		58
Sodium carbonate	9.0	295
Sodium sulfate		2,562
Sodium bisulfite		144
Sodium chromate	6.9	0.861
Sodium silicate		506
Sodium bisulfite		75
Sodium chromate	6.9	0.306
Sodium sulfate		3,312
Sodium bisulfite		52
Sodium silicate	8.5	126
Sodium sulfate		2,308
Sodium carbonate		182
Sodium chromate	9.1	0.146
Sodium silicate		86
Sodium carbonate		240
Sodium chromate	9.3	0.192
Sodium sulfate		2,079
Sodium carbonate		155
Sodium silicate	8.8	73
Sodium sulfate		1,343
Sodium chromate		0.201
Sodium silicate	8.5	119
Sodium sulfate		2,180

[1] Average of three tests.

dium chromate. This variation may be due to the possible oxidizing action of sodium chromate on sodium bisulfite.

There appears to be no direct correlation between the toxicity displayed and the pH. Since the *Daphnia magna* is known to live at a pH range of 6.2 to 9.5, and since the threshold concentrations of all combinations tested were within this range, this would indicate that in no case was pH the sole cause of mortality.

However, the pH may be a contributing factor, as evidenced by the values obtained. For example, sodium silicate when tested with sodium bisulfite has a threshold concentration of 427 p.p.m. at a threshold pH of 8.2; when tested with sodium carbonate, it has a threshold of 98 p.p.m. with a threshold pH of 9.3. Most of the other combinations show this tendency to a lesser degree.

Summary and Conclusions

The method of culturing and testing with *Daphnia magna* as proposed by Anderson has been modified to produce a more standardized procedure; this modification consists of the substitution of standard reference water for the usual lake or stream water as previously employed. Equally satisfactory results were obtained by the new procedure.

Tests were conducted on five inorganic sodium salts by means of this method. The salts were tested individually, in combinations of two, and in combinations of three.

The results of these tests indicate that the thresholds are lowest for the combinations of three and highest for the individual compounds, the combinations of two being intermediate in toxicity. The threshold pH may be a contributing factor in the reduction of the thresholds of the combinations, but no exact evaluation could be made by the procedure employed.

Acknowledgments

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CORROSION OF SHIPS' PROPELLERS IN POLLUTED ESTUARIES

In a "Letter to the Editor" of the British publication *Engineering* (issue of April 24, 1953), A. B. Wheatland and A. Laird, members of the staff of the Water Pollution Laboratory, Watsford, Herts., England, contributed the following:

A fresh example of the injurious effects which may result from the pollution of estuaries has recently come to light.

It was reported to the British Shipbuilding Research Association that the bronze propellers and gun-metal sleeves on propeller shafts of certain vessels using a polluted estuary were subject to excessive corrosion. It was also reported that measurements of the potential difference between the propeller shafting and the hull, when a vessel was moving at full speed, showed that the shafting was normally about 250 mv. more positive than the hull, but that, as the vessel entered the estuary during the summer, the sign of the potential became reversed. This reversal was not observed during the winter. The potential of the shafting was governed by the potential of the propeller and the gun-metal sleeves, which completely covered the section of the shafting exposed to the water. As it was thought that these phenomena were probably connected with the condition of the water in the estuary, the Water Pollution Research Laboratory was consulted.

Experiments made by the laboratory have shown that the potentials of gun-metal and phosphor-bronze electrodes are more positive than mild steel when immersed in aerated estuary water, but become more negative when sulfide is present in the water. Some values of the potentials for various metal rods after immersion for 1 hr. in flowing estuary water, are given in Table I.

TABLE I.—Potentials for Various Metals Immersed in Flowing Estuary Water[1]

Metal	Potential, Sat. Calomel Scale (mv.)	
	Aerated Water	Water Cont. Sulfide[2]
Mild steel	−669	−752
Gun-metal	−175	−778
Phosphor bronze	−203	−779

[1] Salinity, 21.35 g. per 1,000 g.; pH 7.4.
[2] 7.1 p.p.m. as S.

It is known that, during the summer, sulfide is present in the water of the estuary concerned, and it is concluded that its presence is responsible for the reversal of potential and might cause the excessive corrosion of the copper alloys.

STUDIES OF BIOCHEMICAL OXIDATION BY DIRECT METHODS *

III. Oxidation and Purification of Industrial Wastes by Activated Sludge

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The development of a direct method for measuring biochemical oxidation of wastes (1) has resulted in its application to numerous problems concerning the oxidation of sewage and industrial wastes. This paper presents the results of a study of the oxidation and purification of industrial wastes using the direct method. The purpose of this study was to (a) determine the relative importance of several factors affecting the rates of oxidation and purification of various industrial wastes using activated sludge; (b) obtain a correlation between resultant rates of oxidation and purification; and (c) determine what relation existed between B.O.D. loading, resultant sludge accumulation rates, and sludge ages, as well as the oxygen demand of the activated sludges alone.

The factors studied included sludge concentration, waste concentration, sludge acclimatization, sludge age, and temperature. Because of the many experimental data obtained, detailed results are given for one waste in the group studied, the remaining results being presented in summarized form.

Experimental Procedure

Materials Used

The wastes employed were rag, rope, jute, and sulfite cook liquors, boardmill white water, yeast nutrients spent beer, dairy waste (simulated by use of diluted milk), and chewing gum wash water. Where necessary, the nutrient elements nitrogen and phosphorus were added to maintain a maximum B.O.D.: N:P ratio of 60:3:1. All wastes were neutralized to pH 7.

Activated sludge was obtained from the Marlboro, N. J., sewage treatment plant.

For each waste the effect of sludge solids concentration was measured on a range of 500 to 4,000 p.p.m. solids at a constant B.O.D. loading. For the group of wastes the B.O.D. added varied from 1,140 to 1,530 p.p.m. The effect of waste B.O.D. concentration was determined for a B.O.D. range from about 600 to 2,400 p.p.m., using a constant sludge solids concentration of 2,000 p.p.m. The same procedure was used for both normal and acclimatized activated sludge.

Measurement of Oxidation and Purification Rates

Samples of 200-ml. volume and containing the desired waste B.O.D. and sludge solids concentrations were prepared. An aliquot portion was placed in the Warburg apparatus for oxidation rate measurement at 20° C. The major portion of the sample was aerated by agitation in a 500-ml. Erlenmeyer flask at 20° C. using a laboratory shaker operated at 240 oscillations per minute. Aeration by agitation was used to prevent possible foaming difficulties resulting from aeration by submerged diffusion. At stated time intervals

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agitation was halted, the samples were allowed to settle for several minutes, and a small portion of supernatant was removed for measurement of B.O.D. remaining in the waste. At the same time the amount of oxygen utilization was measured on the Warburg apparatus and corrected for the oxygen utilized by a control sample containing activated sludge alone. The recorded oxygen demand at any time interval represented only that amount caused by the added waste B.O.D.

Calculation of Rate Constants

The foregoing procedure made it possible to distinguish between the rates of purification or removal of oxidizable materials from the waste by the sludge, and the rates of oxidation of these materials after their removal in the mixed liquor.

By use of the monomolecular formula, a series of theoretical curves was prepared (Figure 1) relating k value, oxidation time, and oxygen demand exerted or removed expressed as percentage of the 5-day demand. Because of the relative rapidity with which oxidation and purification of wastes are accomplished in the presence of activated sludge, as compared to the "normal" oxidation of domestic sewage, the time intervals used for calculating k values were 2, 4, 6, 12, 24, and 48 hr. From the observed data the k values can readily be obtained from the curves given in Figure 1, using at least four time intervals. The k values obtained from various intervals of time are averaged, the time unit for expressing k values being in terms of days.

Preparation of Acclimatized Sludges

In this paper the term "normal sludge" is used to denote activated sludge obtained from the sewage treatment plant. The term "acclimatized sludge" is used to describe normal sludge acclimatized for oxidation of the particular waste by the following method. A 1-l. sample was prepared containing 2,000 p.p.m. sludge solids and 1,200 p.p.m. waste B.O.D. concentration. After 24-hr. aeration by agitation at 20° C. the mixed liquor was settled and the supernatant was decanted. A new sample was prepared using the same sludge and the pro-

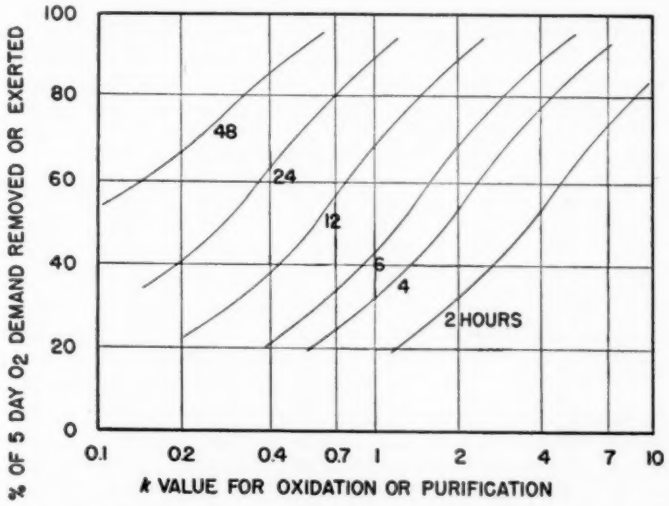

FIGURE 1.—Relationship between k values for oxidation or purification, per cent of 5-day oxygen demand exerted or removed, and time.

cedure was repeated a total of five times. The sludge was then considered acclimatized and used for measurement of oxidation and purification rates as described above.

Preparation of Sludges

For the purpose of this investigation the "sludge age" may be defined as the ratio between the final volatile sludge solids concentration at the end of a 1-day aeration period and the volatile sludge solids produced during the same period. By this definition, sludge age approaches a limiting minimum value of 1 day at high B.O.D. loadings. Under plant conditions of continuous flow this concept of sludge age can be applied by using the ratio of total volatile solids under aeration and the volatile solids produced.

Using sludges acclimatized as described, samples were prepared containing 600, 1,200, and 2,400 p.p.m. sludge solids, and 1,500 p.p.m. added B.O.D. waste concentration. After 24-hr. aeration at 20° C., the sludge solids concentration was adjusted to the original value and the procedure was repeated five times to allow the sludge to reach equilibrium with respect to the calculated sludge age of the sample.

Measurement of Sludge Accumulation Rates

Because of the growing interest in the problem of sludge accumulation during treatment of sewage by the activated sludge process, a study was made of sludge accumulation rates at different sludge solids concentrations for a group of industrial wastes.

Acclimatized sludges were prepared for jute, yeast, and gum wastes as previously described. Using a constant daily B.O.D. loading of 1,500 p.p.m. and three initial sludge solids concentrations—namely, 750, 1,500 and 3,000 p.p.m.—the final sludge solids concentration after 24-hr. aeration was determined and the required amount of sludge was wasted to restore the specified initial sludge concentration. This

TABLE I.—Effect of Sludge Solids Concentration on Rates of Oxidation and Purification of Yeast Nutrients Spent Beer at 1,380 P.P.M. B.O.D. Using Normal and Acclimatized Activated Sludge

Time (hr.)	Oxygen Demand of Waste (p.p.m.)				B.O.D. Rem. in Sup. Liquor (p.p.m.)			
	4,000 P.P.M. Sl. Sol.	2,000 P.P.M. Sl. Sol.	1,000 P.P.M. Sl. Sol.	500 P.P.M. Sl. Sol.	4,000 P.P.M. Sl. Sol.	2,000 P.P.M. Sl. Sol.	1,000 P.P.M. Sl. Sol.	500 P.P.M. Sl. Sol.
(*a*) Normal Activated Sludge								
3	150	135	100	65	290	260	150	150
6	335	230	170	130	520	400	240	240
12	610	505	345	255	855	660	520	480
24	1,120	1,200	1,030	830	1,345	1,320	1,205	1,160
k values	0.45	0.4	0.3	0.25	0.8	0.6	0.4	0.35
(*b*) Acclimatized Activated Sludge								
2	225	190	135	95	740	530	330	150
4	485	345	245	195	1,180	920	580	380
6	755	520	330	280	1,280	1,045	750	630
12	1,120	1,010	685	570	1,330	1,330	1,280	1,220
24	1,360	1,330	1,170	905	1,355	1,355	1,350	1,325
k values	0.9	0.7	0.45	0.35	4.1	2.8	1.4	1.0

TABLE II.—Effect of Sludge Solids Concentration on Oxidation and Purification Rate Constants for Several Industrial Wastes; Normal Activated Sludge Results

Waste	$k_{oxid.}$ Values				$k_{purif.}$ Values			
	4,000 P.P.M. Sl. Sol.	2,000 P.P.M. Sl. Sol.	1,000 P.P.M. Sl. Sol.	500 P.P.M. Sl. Sol.	4,000 P.P.M. Sl. Sol.	2,000 P.P.M. Sl. Sol.	1,000 P.P.M. Sl. Sol.	500 P.P.M. Sl. Sol.
Rag cook liquor	0.25	0.2	0.15	0.1	0.45	0.3	0.3	0.25
Rope cook liquor	0.45	0.25	0.15	0.1	0.6	0.45	0.35	0.3
Jute cook liquor	0.5	0.45	0.3	0.2	1.0	0.9	0.6	0.4
Sulfite waste liquor	0.4	0.3	0.2	0.15	0.75	0.6	0.4	0.3
Boardmill white water	0.45	0.3	0.25	0.2	2.0	1.3	0.65	0.35
Yeast nutrients spent beer	0.45	0.4	0.3	0.25	0.8	0.6	0.4	0.35
Dairy waste	—	0.25	0.2	0.15	—	1.2	0.9	0.6
Average	0.40	0.30	0.20	0.15	0.90	0.75	0.50	0.35

procedure was followed for 10 days and average rates of accumulation were calculated. A similar procedure was used for boardmill white water, where sludge accumulation rates were measured over a 7-day period at 2,000 and 4,330 p.p.m. B.O.D. concentration and 1,000, 2,000, 3,000, and 4,000 p.p.m. sludge solids.

Experimental Results

Inasmuch as the results obtained for yeast nutrients spent beer were considered typical of those for the group of wastes, they are presented in somewhat greater detail. This waste has a B.O.D. of 7,000 p.p.m. and pH of 6.5. It results from the cultivation of bakers yeast by submerged aeration on a molasses media, and consists of unfermented materials present in the molasses as well as metabolic waste products resulting from growth of the yeast cells.

Effect of Sludge Concentration

An increase in sludge suspended solids concentration (using normal activated sludge and 1,530 p.p.m. B.O.D. loading) from 500 to 4,000 p.p.m. resulted in an increase in $k_{oxid.}$ from 0.25 to 0.45. A corresponding improvement was observed for the rate of B.O.D. removal or purification. An increase in sludge solids from 500 to 4,000 p.p.m. caused an increase in $k_{purif.}$ from 0.35 to 0.8 (Table I). A similar trend was observed on acclimatized sludge. An increase in sludge concentration from 500 to 4,000 p.p.m. caused an increase in $k_{oxid.}$ from 0.35 to 0.9 and a corresponding increase in $k_{purif.}$ from 1.0 to 4.1 (Table I).

Similar results were observed for the entire group of wastes. With normal activated sludge the average $k_{oxid.}$ for all wastes increased from 0.15 to 0.40 and the $k_{purif.}$ rose from 0.35 to 0.90 as the sludge concentration was increased from 500 to 4,000 p.p.m. (Table II and Figures 2 and 3). Using acclimatized sludge the average $k_{oxid.}$ for all wastes increased from 0.45 to 1.35 and the $k_{purif.}$ rose from 1.0 to 4.9 (Table III and Figures 2 and 3).

The average oxidation rate constants were found to vary linearly with sludge solids concentration for both normal and acclimatized sludges. The following correlation equations were obtained:

Normal sludge

$$k_{oxid.} = 0.000075 \text{ (p.p.m. sl. conc.)} + 0.12 \quad (1)$$

Acclimatized sludge

$$k_{oxid.} = 0.00025 \text{ (p.p.m. sl. conc.)} + 0.33 \quad (2)$$

There was no linear relation between $k_{purif.}$ values and sludge concentration, for either normal or acclimatized sludges. In these cases k values were found to vary linearly with the log of sludge solids concentration. The fol-

TABLE III.—Effect of Sludge Solids Concentration on Oxidation and Purification Rate Constants for Several Industrial Wastes; Acclimatized Activated Sludge Results

Waste	$k_{oxid.}$ Values				$k_{purif.}$ Values			
	4,000 P.P.M. Sl. Sol.	2,000 P.P.M. Sl. Sol.	1,000 P.P.M. Sl. Sol.	500 P.P.M. Sl. Sol.	4,000 P.P.M. Sl. Sol.	2,000 P.P.M. Sl. Sol.	1,000 P.P.M. Sl. Sol.	500 P.P.M. Sl. Sol.
Rag cook liquor	1.5	1.1	0.9	0.7	6.0	3.6	2.6	1.6
Rope cook liquor	0.8	0.65	0.5	0.35	3.5	2.0	1.4	1.0
Jute cook liquor	0.9	0.7	0.5	0.35	5.0	3.5	2.1	1.1
Sulfite waste liquor	1.5	1.3	0.9	0.6	3.6	2.8	1.8	1.2
Boardmill white water	1.7	1 1	0.75	0.5	9.0	6.6	3.7	1.0
Yeast nutrients spent beer	0.9	0.7	0.45	0.35	4.1	2.8	1.4	1.0
Dairy waste	—	0.6	0.5	0.4	—	3.9	1.8	0.7
Gum wash waste	1.1	0.6	0.45	0.35	3.0	1.5	1.2	0.7
Average	1.35	0.85	0.6	0.45	4.9	3.3	2.0	1.0

lowing correlation equations were obtained:

Normal sludge

$$k_{purif.} = 0.66 \log \text{sl. conc. (p.p.m.)} - 1.46 \quad (3)$$

Acclimatized sludge

$$k_{purif.} = 4.35 \log \text{sl. conc. (p.p.m.)} - 10.9 \quad (4)$$

Effect of Waste Concentration

When 2,000 p.p.m. normal sludge concentration was used, an increase in yeast waste concentration from 690 to 2,760 p.p.m. B.O.D. caused a decrease in $k_{oxid.}$ from 0.5 to 0.25 and a decrease in $k_{purif.}$ from 0.85 to 0.45. Similar results were obtained with acclimatized sludge. An increase in B.O.D. concentration from 690 to 2,760 p.p.m. resulted in a decrease in $k_{oxid.}$ from 1.2 to 0.55 and a drop in $k_{purif.}$ from 3.0 to 1.8 (Table IV).

Average results for a group of wastes showed a decrease in $k_{oxid.}$ from 0.45 to 0.2 and a drop in $k_{purif.}$ from 1.0 to 0.55 as the waste concentration was increased from 655 to 2,620 p.p.m. B.O.D. using normal activated sludge.

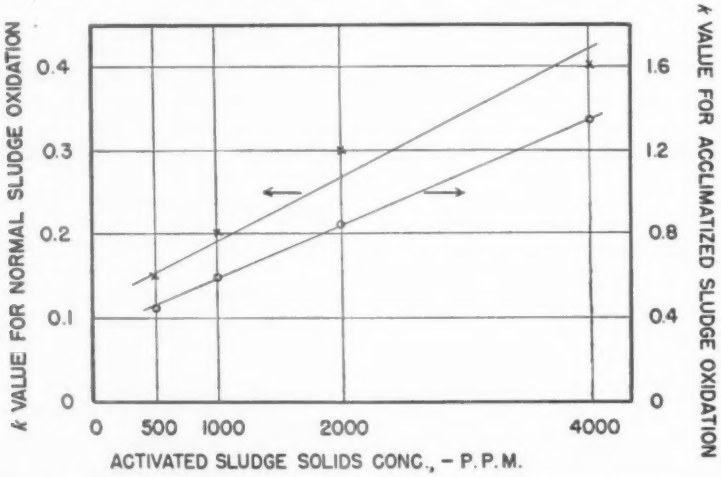

FIGURE 2.—Relationship between normal and acclimatized sludge concentration and oxidation constant *k*.

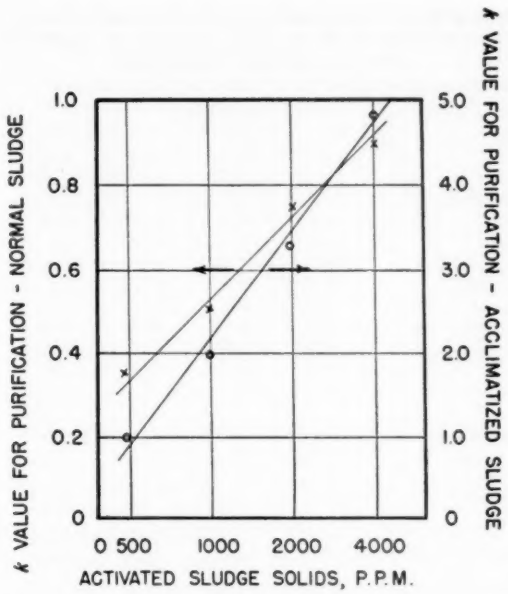

FIGURE 3.—Relationship between normal or acclimatized sludge concentration and purification constant *k*.

TABLE IV.—Effect of Waste B.O.D. Concentration on Rates of Oxidation and Purification of Yeast Nutrients Spent Beer at 2,000 P.P.M. Sludge Solids Concentration Using Normal and Acclimatized Activated Sludge

Time (hr.)	Oxygen Demand of Waste (p.p.m.)			B.O.D. Rem. in Sup. Liquor (p.p.m.)		
	690 P.P.M. B.O.D.	1,380 P.P.M. B.O.D.	2,760 P.P.M. B.O.D.	690 P.P.M. B.O.D.	1,380 P.P.M. B.O.D.	2,760 P.P.M. B.O.D.
(*a*) Normal Activated Sludge						
3	80	135	175	150	260	330
6	185	230	305	240	400	600
12	340	505	580	450	660	1,080
24	615	1,200	1,470	630	1,320	2,265
k values	0.5	0.4	0.25	0.85	0.6	0.45
(*b*) Acclimatized Activated Sludge						
2	140	190	310	310	530	880
4	275	345	580	470	860	1,360
6	405	520	910	565	1,045	1,740
12	640	1,010	1,780	635	1,330	2,610
24	800	1,330	2,230	680	1,355	2,700
k values	1.2	0.7	0.55	3.0	2.6	1.8

TABLE V.—Effect of Waste Concentration on Oxidation and Purification Rate Constants for Several Industrial Wastes Using 2,000 P.P.M. Sludge Solids; Normal Activated Sludge Results

Waste	$k_{oxid.}$ Values			$k_{purif.}$ Values		
	655 P.P.M. B.O.D.	1,310 P.P.M. B.O.D.	2,620 P.P.M. B.O.D.	655 P.P.M. B.O.D.	1,310 P.P.M. B.O.D.	2,620 P.P.M. B.O.D.
Rag cook liquor	0.3	0.2	0.15	0.35	0.3	0.3
Rope cook liquor	0.5	0.25	0.15	0.6	0.45	0.35
Jute cook liquor	0.75	0.45	0.2	1.0	0.9	0.8
Sulfite waste liquor	0.45	0.3	0.2	0.6	0.6	0.4
Boardmill white water	0.45	0.3	0.25	2.2	1.3	0.55
Yeast nutrients spent beer	0.5	0.4	0.25	0.85	0.6	0.45
Dairy waste	0.25	0.25	0.25	0.5	1.2	0.9
Average	0.45	0.30	0.20	1.0	0.75	0.55

With acclimatized sludge $k_{oxid.}$ dropped from 1.25 to 0.6 and $k_{purif.}$ decreased from 4.6 to 1.7 (Tables V and VI, and Figure 4).

Effect of Acclimatization

The exposure of normal activated sludge, which was accustomed to treatment of domestic sewage at relatively low B.O.D. concentrations, to a particular industrial waste for five passages resulted in all cases in marked improvement in rates of B.O.D. removal and oxidation. When yeast waste was used at sludge concentrations from 500 to 4,000 p.p.m., $k_{purif.}$ values rose from a range of 0.35 to 0.8 to between 1.0 and 4.1. Values of $k_{oxid.}$ increased from between 0.25 and 0.45 to between 0.35 and 0.9 (Tables 2 and 3).

When averaged results for eight industrial wastes were used, the acclimatization procedure increased $k_{purif.}$ values from between 0.35 and 0.9 to between 1.0 and 4.9. A corresponding improvement was affected in values of $k_{oxid.}$ which rose from between 0.15 and 0.4 to between 0.45 and 1.35 (Figures 2 and 3).

Further improvement in oxidation and purification rates may be expected with continued feeding of the sludge with a particular waste accompanied by regular wasting of accumulated sludge until the sludge remaining is composed solely of new growth based on the particular waste. This is shown

TABLE VI.—Effect of Waste Concentration on Oxidation and Purification Rate Constants for Several Industrial Wastes using 2,000 P.P.M. Sludge Solids; Acclimatized Activated Sludge Results

Waste	$k_{oxid.}$ Values			$k_{purif.}$ Values		
	655 P.P.M. B.O.D.	1,310 P.P.M. B.O.D.	2,620 P.P.M. B.O.D.	655 P.P.M. B.O.D.	1,310 P.P.M. B.O.D.	2,620 P.P.M. B.O.D.
Rag cook liquor	1.7	1.1	0.85	6.6	3.6	1.6
Rope cook liquor	0.85	0.65	0.45	3.1	2.0	1.1
Jute cook liquor	1.0	0.7	0.45	6.0	3.5	2.0
Sulfite waste liquor	1.7	1.3	0.8	3.6	2.8	1.5
Boardmill white water	1.7	1.1	0.9	7.1	6.6	2.4
Yeast nutrients spent beer	1.2	0.7	0.55	3.0	2.6	1.8
Dairy waste	0.8	0.6	0.45	4.8	3.9	2.4
Gum wash waste	1.2	0.6	0.4	2.6	1.5	0.8
Average	1.25	0.85	0.60	4.6	3.3	1.7

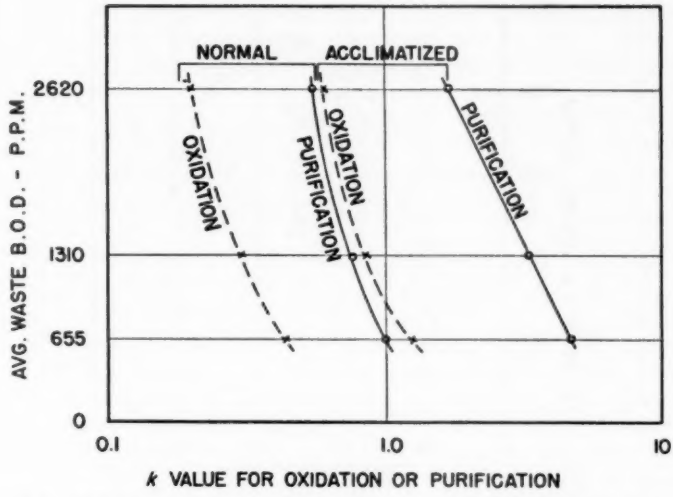

FIGURE 4.—Relationship between B.O.D. of the waste treated and oxidation and purification constant k using 2,000 p.p.m. of normal or acclimatized sludge for a group of eight industrial wastes.

by a comparison of the values of $k_{oxid.}$ given in the foregoing sections for yeast, jute, and chewing gum wastes with those given in the following section on temperature effects.

Effect of Temperature

A study was made of the effect of temperature in the range from 14° to 42° C. on oxidation rates of yeast, jute, and gum wastes. The sludges used had been acclimatized at 20° C. to the particular wastes over a period of several weeks, accompanied by regular wasting of accumulated sludge so that the original sludge had been replaced with fresh growth resulting from exposure to the particular waste.

The results (Figure 5 and Table VII) show that there is a marked increase in oxidation rate as the temperature is increased from 14° to 28° C., with optimum values being obtained between 28° and 36° C. As the temperature is increased further from 36° to 42° C., there is a rapid drop in oxidation rate to the values obtained at 14° C. Optimum k values and first-hour oxygen demands occur at 30°, 33°, and 35° C. for jute, yeast, and gum wastes, respectively.

Effect of Sludge Age

By varying the B.O.D. loading and sludge solids concentration carried in the mixed liquor, it is possible to produce sludges of different ages ranging from a limiting value of one day upwards. A study was made to determine whether sludge age has any effect on the oxidation and purification capacity of the sludge.

The results show that within the range from 1.5 to 4.1 days there is no

TABLE VII.—Effect of Temperature on Oxidation Rate Constants for Oxidation of Yeast, Jute, and Gum Wastes Using 1,500 P.P.M. Added B.O.D. and 1,500 P.P.M. Acclimatized Sludge Solids

Waste	$k_{oxid.}$ Values					
	14° C.	17° C.	20° C.	28° C.	36° C.	42° C.
Yeast	0.5	0.8	1.1	1.35	1.45	0.6
Jute	0.5	0.7	0.9	1.3	1.15	0.45
Gum	0.45	0.6	0.8	1.2	1.3	0.5
Average	0.5	0.7	0.95	1.3	1.3	0.5

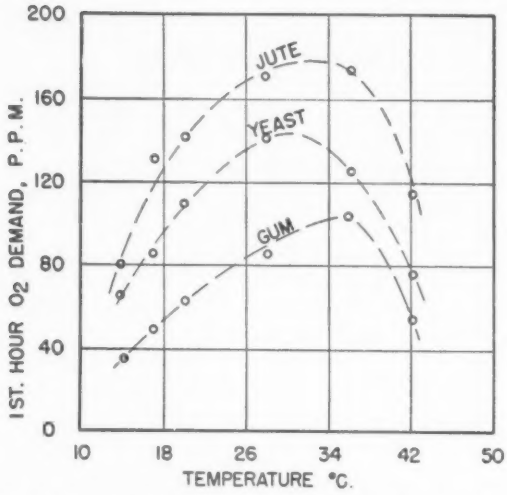

FIGURE 5.—Effect of temperature on the first-hour oxygen demand using 1,500 p.p.m. of 20° C. acclimatized sludge and yeast, jute, and gum waste of 1,500 p.p.m. B.O.D.

significant effect of sludge age on the oxidation or purification capacity of a sludge (Table VIII). As is shown subsequently, this sludge age range covers a B.O.D. loading range from 0.7 to 6 lb. of B.O.D. applied daily per pound of volatile sludge solids carried.

Relation Between Purification and Oxidation Rates

Using the data given earlier, showing the effect of sludge and waste concentration on values of $k_{oxid.}$ and $k_{purif.}$, an effort was made to establish a correlation between the two. (Figure 6.) It was found that a linear relationship existed between the two constants using the averaged k values for the group of wastes, or those for any given waste. The following correlation equations were obtained:

Normal sludge—average for group
$$k_{oxid.} = 0.46\ k_{purif.} - 0.03 \ldots (5)$$
Normal sludge—yeast waste
$$k_{oxid.} = 0.46\ k_{purif.} + 0.08 \ldots (6)$$
Acclimatized sludge—average for group
$$k_{oxid.} = 0.23\ k_{purif.} + 0.19 \ldots (7)$$
Acclimatized sludge—yeast waste
$$k_{oxid.} = 0.18\ k_{purif.} + 0.19 \ldots (8)$$

TABLE VIII.—Effect of Sludge Age on Rates of Oxidation and Purification of Yeast and Jute Wastes Using B.O.D. Loading of 1,500 and 3,000 P.P.M. and 1,250 and 2,500 P.P.M., respectively, at 1,200 P.P.M. Sludge Concentration

Sludge Age (days)	Yeast Waste k Values				Sludge Age (days)	Jute Waste k Values			
	Oxidation		Purification			Oxidation		Purification	
	1,500 P.P.M. B.O.D.	3,000 P.P.M. B.O.D.	1,500 P.P.M. B.O.D.	3,000 P.P.M. B.O.D.		1,250 P.P.M. B.O.D.	2,500 P.P.M. B.O.D.	1,250 P.P.M. B.O.D.	2,500 P.P.M. B.O.D.
1.8	0.8	0.55	2.1	1.2	1.5	0.7	0.45	1.9	0.8
2.5	0.8	0.55	2.1	1.3	2.0	0.7	0.4	1.9	0.9
4.1	0.8	0.55	2.1	1.2	3.2	0.7	0.4	1.9	0.85

Relation Between B.O.D. Loading, Sludge Accumulation Rates, Sludge Age, and Oxygen Demand of Resultant Sludge

A study was made of the effect of B.O.D. loading on the rate of sludge accumulation using the method described previously, for four wastes. A direct linear relationship was observed between the unit rate of volatile sludge solids buildup and the unit B.O.D. loading factor (Figure 7). The following correlation equation was obtained:

Lb. vol. sl. accum. daily =
0.5 × (lb. B.O.D. appl. daily)

It is of interest that the same rate of accumulation was observed for all four wastes, indicating that this relationship may be a general one.

If an increase in B.O.D. loading factor causes an increase in sludge accumulation rate, there must be a corresponding decrease in sludge age, since sludge age was previously defined as the final volatile sludge concentration divided by the sludge accumulation per passage. A hyperbolic relation was observed between B.O.D. loading factor and sludge age (Figure 8), with the equation

(B.O.D. loading factor) (Sludge age − 1) = 1.95.. (10)

The age of a sludge may be expected to have some effect on its own oxygen demand, or what is often referred to as "endogenous respiration." Thus, a young sludge would be expected to have a greater oxygen demand than an old sludge that has been undergoing oxidation in a treatment unit for a longer period of time and is considered well-oxidized. This was found to be the case (Figure 7). A hyperbolic relationship was observed between the

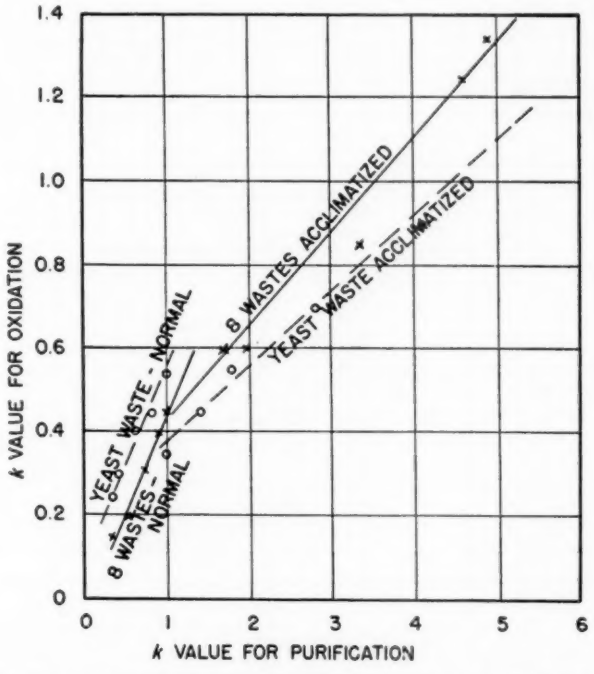

FIGURE 6.—Relationship between oxidation and purification constant *k* using normal and acclimatized sludges and eight industrial wastes.

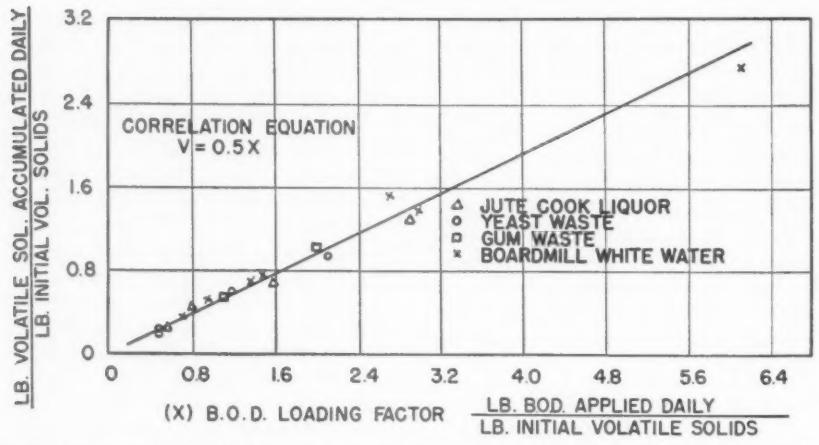

FIGURE 7.—Relationship between B.O.D. loading and volatile sludge solids accumulation for several industrial wastes.

unit 24 hour oxygen demand of the sludge and its age, as follows:

$$(\text{Unit 24-hr. } O_2 \text{ demand} - 0.1)(\text{Sludge age} - 1) = 0.125 \quad (11)$$

Furthermore, this relationship was found to apply to sludges produced with four different wastes, and may again be a general one.

General Discussion

Although the merits of the monomolecular reaction and k-value concept for characterizing rates of oxidation of domestic sewage and industrial wastes are now being reexamined, it is felt that this concept is of value when applied to the study of oxidation and purification of industrial wastes and

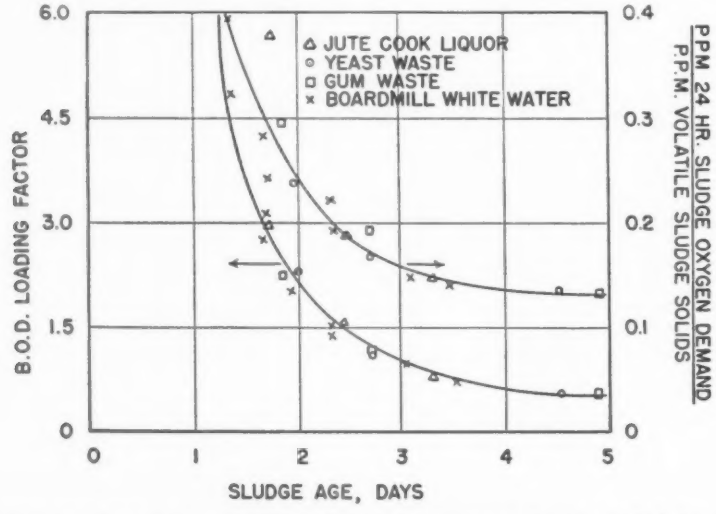

FIGURE 8.—Relationship between B.O.D. loading factor, sludge age, and sludge oxygen demand for several industrial wastes.

sewage by activated sludge for the following reasons:

1. In the great majority of cases in this paper the data were found to fit the monomolecular form satisfactorily so that equal k values were obtained at different points on a given oxidation or purification curve.

2. While the k value is an exponential constant in the monomolecular reaction equation, it also has linear significance at values above 0.2. As shown in Figure 1, if a given oxidation reaction has a k value of 0.3, then 30 per cent of the 5-day oxygen demand is exerted in 12 hr., and if a second reaction has a k value of 0.6 then 30 per cent of the 5-day demand is exerted in half the time, or 6 hr.

3. Since the k values encountered in activated sludge waste systems range from 0.2 to 10 in this study, it can be said that the k value is inversely proportional to the time required to effect a given rate of purification or oxidation, and the k-value concept is therefore well-suited for characterizing such systems.

In general, an increase in sludge concentration caused an increase in both rates of oxidation and purification of either normal or acclimatized sludge. The oxidation reaction was found to be the rate controlling phase in the purification reaction, because the rates of adsorption (purification) were always much higher than the oxidation rates. The importance of activated sludge as an organic adsorbent is emphasized by this point. The logarithmic relation between $k_{purif.}$ and sludge concentration shows that a given increase in sludge concentration in the lower range produces a greater proportionate increase in k than the same increase in sludge concentration at the higher range of sludge concentrations. The reason for this is that the rate of adsorption depends not only on the actual concentration of adsorbent (sludge), but also on the ratio of material to be adsorbed (B.O.D.) to the adsorbent (sludge). At higher sludge concentrations the latter factor decreases, causing a smaller proportionate increase in purification rate.

Since the adsorption reaction proceeds faster than the oxidation phase, there is always excess material remaining to be oxidized on the sludge surfaces so that the linear relation between oxidation rate and sludge concentration is plausible. It is, however, of interest that the same type of correlation equation applies to a given reaction (oxidation or purification) when either normal or acclimatized sludge is used.

Although an increase in waste concentration causes an increase in absolute rates of purification and oxidation, the relative rates expressed as k values decrease because of the larger amount of B.O.D. remaining to be oxidized or adsorbed.

Although sludge and waste concentrations have important effects on the rates of oxidation and purification, the greatest importance should be attached to the effect of acclimatization, a process whereby the numbers of those organisms in the sludge which can metabolize the given waste are greatly increased, and then metabolic patterns altered to accomplish the purification process more rapidly. For a given sludge and waste concentration, acclimatization increased the rates of oxidation and purification from two- to three-fold. Further improvement was obtained by extended acclimatization accompanied by wasting of accumulated sludge in order to eliminate the original sludge entirely.

The manner in which the rate of oxidation varies with temperature is similar to that observed by Sawyer and Nichols (4), who worked with domestic sewage and activated sludge. In comparing oxidation rates at 10°, 15°, and 20°, with that for 25° C. being considered as 100, average values for three wastes of 25, 46, and 76 were obtained, compared to Sawyer and Nichols' (4)

values of 26, 44, and 71. The optimum rates obtained 30° and 35° C. correspond with the optimum range for mesophilic bacterial activity.

The existence of a linear relation between oxidation and purification constants when using either normal or acclimatized sludge is evidence for the close interdependence of the two phases in the over-all purification reaction. Thus, the adsorption capacity of a sludge can be increased by a given set of factors only if there is a corresponding increase in the oxidation capacity of the sludge. The lower slope of the correlation equations for acclimatized sludge (Eqs. 7 and 8) compared to those for normal sludge (Eqs. 5 and 6) indicates that acclimatization causes a greater proportional increase in the adsorptive capacity of the sludge than in the oxidative capacity.

Although sludge age, in the range studied, had no effect on the oxidation or purification capacity, it is conceivable that if the B.O.D. loading was increased to such an extent that the age approached the limiting value of 1 day, it would be so underoxidized that its ability to adsorb and oxidize additional organic material would be impaired. Conversely, if the loadings were reduced to such an extent that the age increased to the point where the sludge began to disintegrate, and become overoxidized, it might also lose the ability to adsorb and oxidize organic material.

The existence of a general relation between B.O.D. loading and sludge accumulation agrees with results of other investigators (2) (3). Since the wastes used were of the soluble organic type, the accumulation of sludge can be attributed to synthesis of new cell material and storage of as yet unoxidized adsorbed organic matter.

The usefulness of the B.O.D. loading factor as a parameter for loading of activated sludge units is shown by its close correlation with sludge age and the condition of the sludge, as indicated by the oxygen demand or endogenous respiration of the sludge alone.

Several points of practical value should be noted. The mixed liquor samples used in this study contained B.O.D. loadings as high as 3,000 p.p.m. per day. Such loadings are equivalent to 5.3 lb. of B.O.D. per cubic yard of aerator capacity, or 144 lb. per 1,000 cu. ft. of aerator capacity. By referring the resultant k values obtained in Tables III and VI to Figure 1, one can appreciate the high B.O.D. loadings and excellent treatment results that are possible with the activated sludge process. For example, when 2,000 p.p.m. acclimatized activated sludge and an average B.O.D. loading of 2,620 p.p.m. are used for the group of wastes, $k_{purif.} = 1.7$ and $k_{oxid.} = 0.6$. Therefore, 90 per cent B.O.D. reduction is effected in 16 hr. and 70 per cent of the 5-day oxygen demand is exerted in 21 hr.

Under such loading conditions there was never any tendency observed for the sludge to disperse or bulk. The sludges settled well and the supernatant liquors were clear. The sludge maintained its flocculent form and because of its strong adsorptive property no dispersed forms were able to become dominant in spite of the high B.O.D. loadings in the mixed liquor.

Despite the great difference in scale between shaker flasks and full-size submerged aeration of activated sludge units, the major difference is in the means of aeration. It is along this line that further work should be done before the promising results in the laboratory can be translated into actual treatment results in the field.

Summary and Conclusions

A study was made of the relative importance of several factors affecting the rates of oxidation and purification of various industrial wastes using normal and acclimatized activated sludge. These factors included sludge concentration, waste concentration, sludge ac-

climatization, sludge age, and temperature. A study was made of the possible relationships between resultant oxidation and purification rates, as well as between B.O.D. loading, sludge accumulation, sludge age, and sludge oxygen demand. Certain practical aspects of the study were pointed out and the following conclusions were reached:

1. The monomolecular reaction and k-value concept are well suited to characterizing the oxidation and purification of industrial wastes by activated sludge.

2. For a given B.O.D. loading, an increase in sludge concentration caused an increase in rates of oxidation and purification. The relation between $k_{oxid.}$ and sludge concentration was linear, whereas that between $k_{purif.}$ and sludge concentration was logarithmic.

3. For a given sludge concentration, an increase in waste concentration caused an increase in absolute oxidation and purification rates, but a decrease in relative rates as indicated by the resultant k values.

4. Acclimatization is the major factor affecting the rates of oxidation and purification of industrial wastes with activated sludge.

5. The effect of temperature was similar to that observed for domestic sewage and activated sludge. The optimum temperature range corresponds to that for optimum mesophilic bacterial activity (30° to 35° C.)

6. A linear relation was observed between $k_{oxid.}$ and $k_{purif.}$, indicating a close interdependence of the two phenomena.

7. Sludge age had no significant effect on the rates of oxidation or purification of industrial wastes by activated sludge.

8. A direct linear relation was observed between sludge accumulation and B.O.D. loading over a wide B.O.D. loading range. Volatile sludge solids accumulated at the rate of 1 lb. for each 2 lb. of B.O.D. loading.

9. Hyperbolic relations were found between B.O.D. loading and sludge age, and sludge oxygen demand and sludge age.

10. The results indicate that B.O.D. loadings of at least 5 lb. per cubic yard or 135 lb. per 1,000 cu. ft. of aerator capacity per day are possible, with resultant B.O.D. reductions of 90 per cent, using 2,000 p.p.m. sludge solids. At higher sludge concentrations, correspondingly higher B.O.D. loadings are possible.

Acknowledgment

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Stream Pollution

EFFECT OF KRAFT MILL WASTES ON STREAM BOTTOM FAUNA *

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Investigations of stream bottom fauna in the Clearwater and lower Snake rivers were undertaken during the summers of 1950 and 1951. The results of studies on bottom fauna in relation to pollution are presented for the lower 12 mi. of the Clearwater River in Idaho and Washington above and below the mouth of the Clearwater (see Figures 1 and 2). Starting of the kraft pulp mill at Lewiston, Idaho, in December 1950, made it possible to obtain a "before and after" picture of stream conditions as affected primarily by this source of pollution and by other untreated or partially treated domestic and industrial wastes that are discharged into these waters.

There have been a number of investigations made of the toxicity of the various components of kraft mill waste to fish and other aquatic life. Cole (3), while studying the effect of kraft black liquor on black bass, rock bass, perch, and large mouth bass, found the material toxic in concentrations of 5,000 p.p.m. Bergström (2) studied the various components of the waste and found that the sulfate soaps were the most toxic to fish. Hagman (6) found that resin acids in sufficient concentrations would harm fish and stated that the safe concentration of these acids was 2 p.p.m. or less. Extrom and Farner (5) concluded from their experiments that bass (*Huro salmoides*), bluegills (*Lepomis macrochirus*), and sunfish (*Lepomis gibbosus*) were unaffected by "river concentrations" of kraft mill waste. For the purpose of the tests, these concentrations were set arbitrarily at 0.4 gal. per 1,000 gal. of digester concentrate, 0.02 lb. per 1,000 gal. of black liquor, and 0.06 lb. per 1,000 gal. of mill sewage. On the other hand, the fish could not live in the wastes themselves.

Owing to the inconclusive nature of these results, Van Horn and associates were impelled to refine the experimental procedures. Results of a study of five Wisconsin kraft mills by Van Horn *et al.* (10) (11) demonstrate the toxicity of certain components of the wastes to fish and fish food organisms. Toxicity tests, using sensitive species of fish and other organisms, indicated that sulfides, mercaptans, resin acid soaps, and sodium hydroxide constitute the greatest hazards. Methods were devised for measuring the amount of these compounds in kraft mill wastes and data from the five Wisconsin mills are presented. In view of the fact that the lowest dilution ratio of mill waste to receiving waters for these mills under study was 1:94, and in another instance not presented 1:73, it was concluded that the resultant concentration of potentially harmful substances in the wastes was too low to be a hazard to fish and other aquatic forms in the waters under study.

* Presented at Western Sectional Meeting, Ecological Society of America; Corvallis, Ore.; June 16–19, 1952.

Methods

Samples of bottom fauna from riffles were collected by means of the Surber (9) square-foot bottom sampler with trailing net. Because of the predominantly rocky bottom and the swiftness of the current, it was not practical to collect samples from pools by conventional hand dredging operations. Therefore, all results of biological sampling are based on riffle samples. Dissolved oxygen determinations were made by using the sodium azide modification of the Winkler test. Other physical, chemical, and biological tests were likewise performed according to "Standard Methods" (1). Interpretation of the samples of bottom fauna is based on the ecological classification originated by Kolkwitz and Marsson (7) (8) and modified by other members and advisors of the Committee on Standard Methods, American Public Health Association.

Location of Sampling Stations

The stations (Table I) have been designated by the combination of initial of the stream name with the number of miles from the stream mouth to the station. Stream distances were obtained from the maps of the U. S. Army Corps of Engineers (scale 1 in. = 10 mi.), which for some streams show river miles at 50-mi. intervals and at definite points such as stream confluences. In some instances, the biological sampling stations did not correspond exactly with the stations where other samples were collected, because to find favorable areas for bottom sampling it was sometimes necessary to travel several hundred feet up or downstream from the predetermined point.

Physical-Chemical Features

Because of the flow characteristics of the Clearwater River and the form of its channel, the pulp mill wastes were not mixing thoroughly, but hugged the south side of the river all the way to the Snake. There was a definite brownish color and an odor of mill wastes in the water of this section, whereas the north side of the river was clear and free from odor of mill wastes. Rocks and gravel on the stream bed in the affected area were coated with a heavy brown slime of aquatic fungi and bacteria. Waving, felt-like masses of sewage fungi (*mostly Sphaerotilus sp.*) grew in profusion attached to sticks and rocks throughout the polluted stretch of the Clearwater. Differences in bottom fauna over that of the unaffected areas of stream bed were also observed and are described in a later section of this paper. There was no observable effect of the mill wastes upon color and odor of the Snake River waters below the mouth of the Clearwater.

The results of the physical and chemical tests are presented in Tables II and III. In the interest of brevity, comment is made only on the relationships of D.O. and B.O.D.

TABLE I.—Location of Sampling Stations and Sources of Pollution

Station No.[1]	Description
	(a) Clearwater River
Cl–12	At Spalding; riffle above bridge on U. S. Highway 95
Cl–4	At Washington Water Power dam (chemical samples only)
Cl–3.8	At first riffle downstream from Washington Water Power dam; kraft pulp mill, Potlatch Forests, Inc., located at this point; waste discharge from this 150-ton mill is at Mile 2.1, below the Lewiston municipal water plant
Cl–2.7	Mouth of tail race from Washington Water Power plant (on Potlatch Forests, Inc., property)
Cl–2.2	Opposite Lewiston municipal water plant
Cl–1.8	At new auto bridge
Cl–1.6	At old auto bridge
Cl–0.6	At railroad bridge
Cl–0.3	Main sewer outfall, untreated sewage from city of Lewiston, Idaho
Cl–0	Mouth of Clearwater River
	(b) Snake River
S–135.7	0.2 mi. above interstate bridge at riffle along upper end of island
S–135.5	At interstate bridge (Lewiston-Clarkston)
S–134.5	Above Clarkston sewer outfall (primary treatment plant)
S–128	About 7 mi. downstream from mouth of Clearwater, at riffle near small schoolhouse on north side of river

[1] River mileage above stream mouth.

TABLE II.—Results of Physical-Chemical Analyses of Clearwater and Snake Rivers for 1950[1]

Station	Water Temp. (° C.)		Turbidity (p.p.m.)	pH	Alk., as $CaCO_3$ (p.p.m.)		Ca (p.p.m.)	Mg (p.p.m.)	NO_3, as N (p.p.m.)	PO_4 (p.p.m.)	Diss. Oxygen		5-Day B.O.D. (p.p.m.)
	Aug.	Sept.			Bicarbonate	Carbonate					Time (PM)	(p.p.m.)	
Cl-12	22	15	<5	7.2	0	36.5	6.0	1.7	0.16	0	2:45	8.2	0.5
Cl-4	23	16	<7	7.1	0	25.0	5.2	1.9	<0.05	0	3:15	7.7	0.8
Cl-2.7	22	14	<7	6.9	0	27.0	5.6	1.9	<0.05	0	3:30	8.1	0.5
Cl-2.2	22	15.5	<7	7.2	0	24.0	5.2	1.9	<0.05	0	4:25	9.0	0.9
Cl-1.6N	24.5	16.5	60	7.2	0.0	31	6.0	2.4	0.05	0	2:15	8.3	—
Cl-1.6S	24.5	16.5	<5	7.2	0	31	6.8	2.4	0.05	0	2:15	7.8	—
Cl-0.6	—	14	5	7.1	0	30	5.6	1.9	<0.05	0	10:15	7.9	—
Cl-0	22	14	5	7.1	0	28	4.4	1.7	0.05	0.1	3:45	8.7	1.8
S-135.7	22	16.5	30	8.4	6.0	132.0	41	14	0.58	0.1	3:50	10.9	3.8
S-135.5	22	16.5	30	8.4	5.0	141.0	41	14	0.53	0.1	3:00	10.9	2.9
S-134.5	26	—	—	—	—	—	—	—	—	—	3:10	10.6	2.8
S-128	26.5	16.5	24	8.5	7.0	136.0	40	13	0.5	0.1	3:10	10.2	2.5

[1] All results refer to determinations made September 26–28, except D.O. and 5-day B.O.D. The latter were determined August 14–16.

In 1950 (August), the daytime dissolved oxygen ranged over 7 p.p.m. in the Clearwater and over 9 p.p.m. in the Snake. The B.O.D. in August 1950 averaged less than 3 p.p.m. in the Clearwater at all stations except below the sewers at Lewiston, where the B.O.D. was 3.8 p.p.m. In the Snake River, the highest B.O.D. found was 2.8 p.p.m. The effect of pollution from the pulp mill in 1951 was shown by slight decreases in D.O. and increases in B.O.D. Despite the additional waste content of the lower Clearwater in 1951 over that present in 1950, the effect on the D.O. resources in the river was not striking at the time of the later investigation. The D.O. ranged above 6.0 p.p.m. and the B.O.D. was less than 6.0 p.p.m.

Biological Features

Investigation of August 14–18, 1950

The results of the 1950 investigation are summarized in Table IV and Figure 1. The data show that the Clearwater River enters the 11-mi. stretch above its confluence with the Snake River in good condition with respect to the balance of dissolved oxygen to oxygen demand and with no apparently harmful toxic substances from upstream pollution sources. This is based on the samples from near the Spalding bridge (Sta. Cl-12). The variety of organisms and percentage of

TABLE III.—Results of Physical-Chemical Analyses of Clearwater and Snake Rivers for 1951

Station	Date	Water Temp. (° C.)	Turbidity (p.p.m.)	pH	Tot. Alk., as $CaCO_3$ (p.p.m.)	Diss. Oxygen (p.p.m.)	5-Day B.O.D. (p.p.m.)	Ca and Mg, as $CaCO_3$ (p.p.m.)
Cl-12	8/28	18.5	7	7.0	28	8.15	0.45	7
Cl-4	8/28	20	7	7.1	27	8.2	0.4	6.8
Cl-2.2	8/31	18.5	12	7.1	31	7.7	0.9	7.1
Cl-1.8S	8/29	19	—	6.9	31	6.9	2.75	8.6
Cl-1.8N	8/29	20	—	7.1	33	6.8	5.7	10.8
Cl-1.6S	8/29	20	—	7.1	33	6.8	5.7	10.8
Cl-1.6N	8/29	20	—	7.0	26	8.9	1.4	6.9
Cl-0.6S	8/30	18.5	—	7.1	30	8.0	1.3	7.4
Cl-0.6N	8/30	18.5	—	7.1	28	8.6	0.8	7.0
Cl-0S	8/30	18.5	18	7.1	36	6.8	6.1	9.6
Cl-0N	8/30	18.5	35	7.1	29	8.5	0.7	6.6
S-135.5	8/30	18.5	30	8.4	144	8.8	0.95	46.1
S-128S	8/30	18.5	24	8.4	130	8.2	0.6	42.7
S-128N	8/31	18	22	8.3	117	9.6	1.55	41.2

clean water forms is greater at this upstream control station than at any other downstream point. There are 10 families, genera, and species represented and, of the total numbers of organisms, 93 per cent are clean-water organisms. According to Davis (4), the quantity of bottom fauna is poor when there are but 0.72 per square foot of bottom area. This is based on a criterion of 2 g. or more of organisms per square foot of bottom, which is considered rich from the standpoint of fish food production.

The aquatic insect larvae were represented by three families of caddis flies (*Hydropsychidae, Brachycentridae,* and *Philopotamidae*), one of mayflies (*Heptagenidae*), one beetle family (*Elmidae*) midges (*Tendipedidae*), and stoneflies (*Plecoptera*). No aquatic annelid worms were found. Of all these groups, the stoneflies are the most sensitive to pollution. In some cases it is not practical to identify the immature stages of certain insect larvae, for example, to genera or species. In these instances the family name is given. Others may be identified to genus and species. The second column in Table IV refers to family, genus, or species, and gives a general indication of the numbers of kinds of organisms.

Pollutional organisms were found at Stations Cl-2.7 and Cl-2.2 in small numbers; at Station Cl-0, near the mouth of the Clearwater, 38 per cent of the total organisms were in the pollutional category (sludge worms, leeches, etc.). Despite this fact, there were several moderately sensitive mayfly nymphs in the samples from Station Cl-0, which would be eliminated by gross pollution. The occurrence of the highly sensitive stoneflies is also significant. As already mentioned, some were found at Spalding. Small numbers also occurred at Stations Cl-3.8, Cl-2.2, Cl-1.8N, Cl-1.8S S-135.7, and S-128.

Investigation of August 27–31, 1951

The consistently rocky bottom of the Clearwater River was sampled in the

TABLE IV.—Results of Analyses of Bottom Fauna from the Clearwater and Snake Rivers above and Below Lewiston Idaho, August 14–18 1950

Station	Number of Families, Genera, or Species	Weight of Organisms (g./sq.ft.)	Per Cent of Total Number Individual Organisms		
			Pollutional	Facultative	Cleaner
(*a*) Clearwater River					
Cl-12	10	0.72	—	7	93
Cl-3.8	4	0.1	—	67	33
Cl-2.7	5	0.2	7	50	43
Cl-2.2	5	0.2	8	71	21
Cl-1.8N[1]	6	0.13	—	33	67
Cl-1.8S[2]	5	0.07	—	40	60
Cl-0.6	5	0.1	—	44.5	55.5
Cl-0	7	0.55	38	34	28
(*b*) Snake River					
S-135.7	8	1.1	—	36	64
S-135.7	8	1.0	—	32	68
S-135.5	8	0.25	—	9	91
S-128	6	0.43	—	20	80
S-128	10	2.0	—	25.5	74.5

[1] North bank.
[2] South bank.

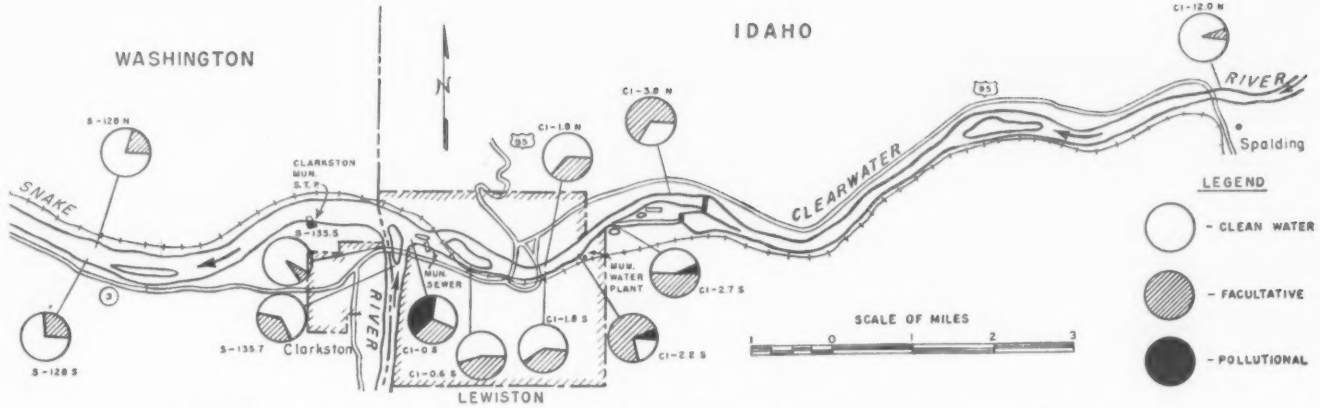

FIGURE 1.—Bottom fauna of Clearwater and Snake Rivers at Lewiston, Idaho, August 14–18, 1950.

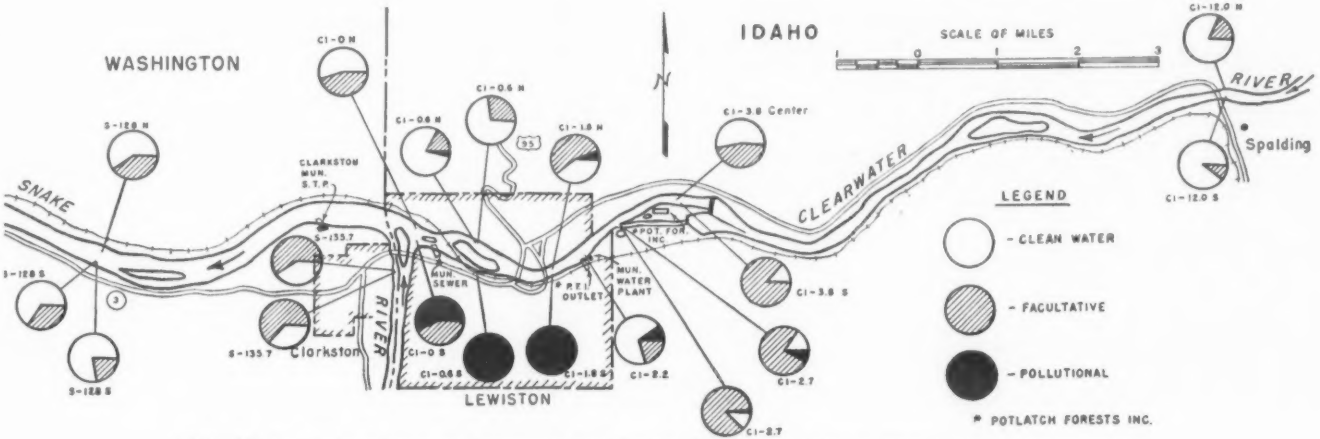

FIGURE 2.—Bottom fauna of Clearwater and Snake Rivers, at Lewiston, Idaho, August 27–31, 1951.

same manner as in 1950, with 21 sq. ft. covered at 7 stations and 7 sq. ft. covered on the Snake River (Figure 2). Because of the apparent difference in water quality on the south side of the Clearwater below the kraft pulp mill outfall, compared to the north side, an effort was made to secure as complete a cross-section of the river at each station as was practicable.

Mention was made in the foregoing section of the occurrence of pollution-sensitive stonefly nymphs at almost all stations along the Clearwater in 1950. Large numbers of cast skins of stonefly nymphs were observed in 1951 adhering to rocks above the water line at Cl-12 and Cl-3.8. Additional cast skins were not found at any other point except on the north bank of the river from the mouth upstream about ¾ mi. (Cl-0 to above Cl-0.6). This evidence of avoidance by stoneflies of the more polluted south side of the Clearwater is borne out by the results of the samples where stoneflies were found in the fauna from Cl-12, Cl-3.8, Cl-1.8N, and Cl-0.6N.

Pollutional organisms (such as sludge worms) were predominant, however, in the stretch along the Lewiston waterfront below the water plant, and continued down to Station Cl-0S (see Figures 1 and 2, and Table V). Semi-tolerant mayfly nymphs, which had occurred in the south channel of the Clearwater a few feet above the Snake River, were not found during the 1951 survey, but worse conditions were apparently prevented by dilution to the extent that a few facultative midge larvae were able to survive.

Owing to the effect of wood sugars in the pulp mill wastes, profuse growths of sewage fungi, such as *Sphaerotilus* sp., were observed all along the south side from Cl-2.2 to Cl-0. Intermingled with the strands of fungi there occurred large numbers of minute sludge worms (*Dero* spp.), which are commonly found in polluted streams and in sewage filters. Table V shows the effect of pulp mill wastes and other pollution on the bottom fauna.

Reference is made to Stations Cl-1.8, Cl-0.6, and Cl-0, each with respect to the north and south channels. These are at the new highway bridge, above the Union Pacific Railroad bridge, and in the mouth of the Clearwater River. The samples from the north side had a variety of organisms (8, 6, and 11 families and genera) with a moderately high production (1.5 to 2 g.) per square foot of bottom area and a predominance of clean-water or facultative organisms. The south side samples, by contrast, had only one or two kinds of organisms, together with only trace weights per square foot; of those organisms present, 100 per cent were pollutional in the samples from Cl-1.8S and Cl-0.6S, and 57.2 per cent were pollutional in Cl-0S.

Discussion

Although the productivity of bottom organisms varies with the physical characteristics of the bottom and pattern of stream flow in any given locality, as well as with the available nutriment, some trends may be observed in the results of the 1950 investigations, as follows:

1. The Snake River was apparently more productive above and below the Clearwater than the Clearwater River itself.

2. The upstream control station near Spalding was three to ten times as productive as any other station downstream in the Clearwater, except Station Cl-0, where the pollutional organisms were present in appreciable quantity and numbers. This low biological productivity of the Clearwater in contrast to the Snake is borne out by the tests for chemical constituents which contribute to the production of animal and plant life.

The data from the earlier investigation indicate mild pollution of the

TABLE V.—Results of Analyses of Bottom Fauna, August 27–31, 1951

Station	Number of Families, Genera, or Species	Wt. of Org. (g./sq.ft.)	Per Cent of Total Number Individual Organisms		
			Pollutional	Facultative	Cleaner
(a) Clearwater River					
Cl–12N	9	0.55	—	18.5	81.5
Cl–12S[2]	15	2.85	—	8	92
Cl–3.8N[1]	12	1.17	—	46.3	53.7
Cl–3.8S[2]	8	0.55	—	86	14
Cl–2.7	7	—	2.3	86.5	11.2
Cl–2.7	3	0.1	4	80	16
Cl–2.2	6	—	10	20	70
Cl–1.8N[1]	8	—	5.55	55.5	38.95
Cl–1.8S[2]	2	Tr.	100	—	—
Cl–0.6N[1]	6	1.7	1.9	22	76
Cl–0.6S[2]	1	Tr.	100	—	—
Cl–0N[1]	11	0.75	—	65	35
Cl–0S[2]	3	0.25	57.2	42.8	—
(b) Snake River					
S–135.7	6	1.3	—	58.8	41.2
S–135.7	10	0.75	—	63.7	36.3
S–128N[1]	10	0.6	—	39.6	60.4
S–128S[2]	10	3.5	—	22.2	77.8
S–128S	7	1.7	—	34.2	65.8

[1] North bank.
[2] South bank.

Clearwater, particularly at Station Cl-0 near the junction with the Snake River. The fact that highly sensitive stonefly nymphs occurred at almost all stations along the Clearwater, except Station Cl-0, as well as in the Snake River, indicates that the then existing pollution along the Lewiston waterfront and in the Snake above and below the confluence of the rivers was not sufficiently potent to eliminate these sensitive organisms. The occurrence of moderately sensitive mayflies in the mouth of the Clearwater indicates adequate dissolved oxygen content and freedom from dangerous concentrations of harmful toxic substances in the water or in the deposits on the river bottom.

The investigation of 1950 and the later one of 1951, although brief and at identical seasons of the year, disclosed evidence of marked effect of pollution from all sources, sanitary and industrial, in the lower 2.2 mi. of the Clearwater River. Except for small increases in certain chemical constituents of the water and in B.O.D., the water tests that were made failed to show any marked deterioration in water quality. However, the pollution effects were obvious on the fauna and flora of the stream bed. The heavy growths of slime and sewage fungi on the south side of the river flourished in response to the high carbohydrate content of the pulp mill and sanitary wastes, but on the north side, out of reach of these wastes, the river bed was little changed throughout the 12-mi. section from Spalding to the Snake River.

Since the more recent investigation the pulp mill has reconstructed its outfall to discharge 150 ft. out from the bank of the river in the south chan-

nel. Although this has resulted in decreasing nuisance from excessive foaming, there is a continued tendency for the waste to resist mixing with the total flow of the Clearwater on its way to the Snake. Because of the bottom configuration in the stream and the channeling of flow, the actual dilution of the waste is not known. It may be assumed, however, that one-half of the total stream flow would be available for dilution. Based on minimum stream flow in this section of the Clearwater of 2,100 c.f.s.—an extreme low flow reading of 500 c.f.s. was recorded in the winter of 1937—and a total waste volume of about 20 c.f.s. (12 m.g.d. at that time), the dilution ratio would be 1:50. Whether or not the concentration of wastes present in the stream was sufficient to be harmful to fish was not determined; however, there was evidence that the pollution disrupted the communities of bottom organisms that existed prior to operation of the kraft mill.

Whether the toxic substances known to be present in kraft mill wastes were being diluted sufficiently at the time of the investigation was not determined, but presumably, harmful toxic effects would be expected only at times of lowest flows in the river. The effect of these wastes on the balance of nutrients and resultant food chains has probably been more serious in this case than any toxic effect. The high content of carbohydrates in the mill wastes has stimulated heavy growths of sewage fungi, which have coated the bottom deposits and the rocks in the riffles and have largely crowded out normal bottom organisms.

Summary and Conclusions

1. Investigations of water quality of the lower 12 mi. of the Clearwater River, Idaho, and the Snake River above and below the mouth of the Clearwater, were conducted in August of 1950 and 1951.

2. This paper includes the biological studies on bottom fauna, with some discussion of correlated physical and chemical features. Owing to swiftness of the rivers and the predominantly rocky bottom, all bottom samples were collected in shallow riffles by using the Surber square-foot bottom sampler with trailing net. On the Clearwater River 49 sq. ft. were sampled; on the Snake, 19 sq. ft.

3. Prior to November, 1950, the major sources of pollution on the lower Clearwater River (12-mi. section under study) were the untreated municipal and industrial wastes from the City of Lewiston, Idaho. Beginning late in 1950, the kraft pulp mill at Lewiston started operation and began discharging wastes into the Clearwater at a point immediately downstream from the municipal water treatment plant (Cl-2.2).

4. The investigation of August, 1951, showed a deterioration in visible water quality and in the character of the stream bed downstream from Station Cl-2.2, where the effluent from the sulfate pulp mill is discharged. Under conditions of flow at that time, most of the effect of the waste was limited to sections of varying width on the south side of the river.

5. In general, the water in the Clearwater was less turbid and softer than in the Snake River.

6. Although dissolved oxygen and biochemical oxygen demand were little affected by the discharge of pulp mill wastes to the stream, the presence of toxic substances (sulfides, mercaptans, and resin acid soaps) known to be components of kraft pulp mill wastes, and carbohydrate fractions, which stimulate growth of sewage fungi, rendered conditions in the affected areas of the Clearwater River untenable for most bottom fauna normally expected to be found in such a river.

7. The Snake River and those areas of the Clearwater not physically within the zone of influence of the wastes

were essentially comparable biologically in the two successive years under investigation.

Acknowledgments

The author is grateful to the Idaho Department of Public Health for the chemical analyses, and the Idaho Department of Fish and Game, the Washington Pollution Control Commission, and the City of Lewiston, Idaho, for generous assistance during the investigations. For the early planning and the first field investigation of his predecessor, A. F. Bartsch, he also wishes to express thanks.

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SEWER MAINTENANCE RECORDS ARE A MUST!*

BY JAMES L. CAREY

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The keeping of costs and records, according to the opinion of most maintenance men, is a nuisance which interferes with productive work. They feel that this is something the "brass" is paid to do, and should not in any case be allowed to interfere with the primary function of getting the work done.

This attitude, if permitted to prevail, often boomerangs unpleasantly and unexpectedly upon the very persons to whom cost and record keeping would confer the greatest benefits. Take, for example, the preparation of the annual budget request for equipment, repairs, replacements, and personnel. The superviser who keeps inadequate records, or no records at all, is unable to substantiate his request for needed items with the cold unassailable facts and arguments that such records would provide. Being thus unable to properly "sell" his immediate superiors upon the reality and importance of his needs, it goes without saying that these items, unsupported as they are by factual evidence, almost never reach the attention of the men holding the purse strings of city government. The keeping and use of adequate cost and performance records would have eliminated this unfortunate situation.

A well-planned sewer maintenance organization and program requires records upon which to determine efficient and intelligent use of personnel. There are certain locations in the sewer system where cleaning is required more often than usual, where root and grease troubles are more than ordinarily prevalent, and where complete or partial stoppages predominate. Is it too much to ask that adequate records be kept so that available personnel may be intelligently distributed in accordance with the greatest need?

Safeguard Against Damage Claims

It should be remembered, also, that stoppages often constitute a health menace or a potentially successful damage claim against the city. Here again, the keeping of adequate records will assist in reducing to a great degree or entirely eliminating these hazards.

Another aspect of damage claims against the municipality for allegedly improper or inadequate maintenance of the sewer system deserves consideration. This is the necessity for keeping records that will make you a valuable and intelligent city witness and give credence to your testimony. In such cases adequate records showing dates of inspections, names of personnel making such inspections, and notations of conditions encountered or observed

* Presented at 25th Annual Meeting, California Sewage and Industrial Wastes Assn.; Santa Barbara, Calif.; Apr. 22–25, 1953.

are invaluable. Moreover, it frequently happens that there is a considerable time interval between the occurrence of the "incident" and its disposition by the courts. The human memory is notoriously faulty and untrustworthy and cannot take the place of evidence. Written records are again the department's best safeguard.

Records Show Needs

Cost and performance records are important for many additional reasons, among which are that they effectually spotlight the following needs:

1. Replacement of obsolete equipment.
2. Repairs of faulty or defective equipment.
3. Revision of methods, procedures, or program.
4. Re-evaluation of personnel performance and efficiency.

In the Sewer Maintenance Division of the City of Los Angeles there has been developed an extensive system of cost and performance accounting. The success and value of such a system depends primarily upon the accuracy and adequacy of the reports turned in by the individual foremen. In line with this thinking there is used a daily time and work report, showing certain "work function numbers," covering as nearly as possible all items of work ordinarily encountered in the operation and maintenance of sewers, storm drains, drainage channels, and appurtenant structures. In addition to these work function numbers, certain significant items, such as hours worked and units of work (feet of sewer or storm drain cleaned, feet of sewer flushed, number of catch basins cleaned, etc.), also are entered. This time and work report is forwarded to the Bureau of Accounting, which, by use of I.B.M. equipment, makes monthly and fiscal-year-to-date compilations for the benefit of monthly and annual study and appraisal by the Sewer Maintenance Division.

Although the corresponding department in another municipality may not have I.B.M. equipment, and may not employ an elaborate system of record keeping, it is nevertheless not only possible but imperative that records on certain basic work be kept and used. The ingenuity and resourcefulness of the individual can be counted upon readily to supply any lack of record keeping device and method once he is sold upon their inherent value to his department.

OPERATIONAL EXPERIENCES AT THE EAST BAY MUNICIPAL UTILITY DISTRICT PLANT *

By Elmer E. Ross

Superintendent, Sewage Treatment Plant, East Bay Municipal Utility District, Oakland, Calif.

The sewage collection and treatment system designed, constructed, and operated by the East Bay Municipal Utility District serves the cities of Alameda, Albany, Berkeley, Emeryville, Oakland, and Piedmont. The first of these border the east shoreline of San Francisco Bay for a distance of approximately 15 mi. and contribute both sanitary sewage and a variety of industrial wastes. Piedmont contributes only domestic sewage.

The interceptor system consists of

* Presented at 25th Annual Meeting, California Sewage and Industrial Wastes Assn.; Santa Barbara, Calif.; April 22–25, 1953.

approximately 21 mi. of reinforced concrete pipe sewers ranging in size from 24-in. to 108-in., and includes 10 sewage lift stations varying in capacity from 0.5 to 7 m.g.d. and one booster pumping station of 57-m.g.d. capacity.

Plant Description

The treatment plant is of the primary type, designed to handle an average dry-weather flow of 128 m.g.d. and a maximum rate of 291 m.g.d. Facilities are provided for prechlorination, coarse screening, grit removal, sedimentation, and sludge digestion. Sludge from the digesters and the effluent from the plant is discharged into the deep waters of San Francisco Bay through an outfall sewer approximately 3 mi. long, the last mile of which lies on the floor of the Bay.

Pumping stations are provided at the treatment plant to lift the raw sewage from the interceptors to the treatment process and for pumping the plant effluent when the gravity capacity of the outfall sewer is exceeded because of the flow rate and tide.

Interception of sewage from the various cities was started in November 1951. The cut-in of sewers started with those nearest the plant and progressed upstream. The initial flow was approximately 20 m.g.d. This has increased until the current flow is approximately 55 m.g.d. At the time the plant was placed in operation, the sludge digestion plant was still under construction. Until its completion the holding period in the sedimentation basins was kept to a minimum, the settled sludge being returned to the plant effluent. The digestion plant was completed in April 1952, at which time the digestion tanks were filled with sewage, brought to temperature, and raw sludge was added. Burnable gas was produced approximately 35 days after the first additions of raw sludge. No difficulty was experienced from foaming during the digester break-in period.

During the cut-in period it was the practice to sample all newly connected sewers and test for the presence of salt water, because many of the sewers in the area are below sea level. As a result, the entry of salt water into the system from broken sewers or leaky bulkheads was quickly detected and necessary repairs were made.

Types of Difficulties

The operational difficulties experienced during the 16 months the system has been in operation have been of the following general types: (a) those caused by the breakdown of plant equipment or its failure to operate as intended; (b) those caused by storm waters, and (c) those caused by the presence of industrial waste in the sewage.

Equipment Operation Problems

The problems involving equipment operation have generally been of the type one might expect to experience in placing any complex mechanical installation in operation, particularly when manned by untrained personnel. They have been in the nature of malfunctions and breakdowns of machinery due to defective parts, and "bugs" in the complex automatic control systems, with two exceptions that are worthy of note.

The first of these involved the operation of check valves on the main sewage pumps. These valves are of the tilting-disc type and are installed between the main pump and the short vertical transition terminating at the inlet to the grit chambers. During preliminary testing of the pumps these valves were found to slam shut with such severe shock when the pump stopped that it was feared damage to the disc and its seat would soon result. It was thought that the rapid reversal of the water column in the discharge was causing the valve to slam. This could be prevented by the installation of a dashpot to cushion the valve clos-

ure. Provision had been made in the design of the valve body and disc to permit the installation of such a device, as these are sometimes necessary. However, these dashpots were not immediately available, and another solution to the problem was sought. Experiment disclosed that the introduction of compressed air into the valve behind the disc just prior to closure entirely eliminated the slam, leading to the belief that cavitation was occurring behind the disc as a result of the reversal of flow, and that the air kept the pressure behind the disc above the vapor pressure, preventing the formation of a vapor bubble, the collapse of which was producing the noise and shock.

The success of this experiment led to the piping of compressed air to the upstream side of each of the check valves. Controls were installed to permit injection of air for a period of approximately 3 sec. while the pump is decelerating and the valve closing. This system has been working satisfactorily.

The other equipment problem worthy of note involved the pre-chlorination system. Facilities were provided for the addition of chlorine solution to the sewage in the intake structure where the two interceptors terminate, just upstream from the headgates of the main sewage pumping station, where conditions were considered ideal from the standpoint of mixing and contact time.

Diffusers were located in the invert of each of the interceptors at the point of discharge into the intake structure. These diffusers contain holes located so as to distribute the solution uniformly and at right angles to the direction of flow. A third diffuser is located in the center of the intake structure.

When pre-chlorination was first attempted, strong chlorine fumes were detected in the atmosphere in the vicinity of the point of application. The fumes were present at all dosages, all sewage flows, and all depths of submergence of the diffusers. The fumes, being highly corrosive, quickly attacked and caused deterioration of all metal work and bleached out paint in the vicinity. To prevent serious damage to equipment, pre-chlorination was stopped.

It was first thought that the diffusers had become partially plugged with sand, and that high-velocity jets from the few open holes were breaking the surface, liberating free chlorine. However, the fumes were still present after the diffusers had been dismantled and cleaned.

Pre-chlorination of the sewage was necessary, however; and, as neither time nor laboratory facilities were then available for a study of the problem, other points of application of the solution were tried in an effort to find where and how chlorination could be accomplished satisfactorily.

It was found that satisfactory results could be obtained by discharging the solution into the sewage in the wet wells of the pumping station. Pre-chlorination of the sewage was accomplished in this manner during the remainder of the season.

Several theories have been advanced as to the cause of this condition, one being that there is insufficient submergence of the diffusers, with the result that the solution breaks the surface, liberating chlorine. However, varying the depth of submergence from 1 to 7 ft. does not seem to change the condition significantly.

Another theory that has been advanced is that conditions are favorable for the formation of nitrogen trichloride, either when the chlorine is mixed with the injector water (plant effluent) or by reaction with the sewage itself. Tests to date have failed to substantiate this theory.

Laboratory facilities now being available, a comprehensive study is being made to determine the causes of the condition and what, if any, changes

are necessary in the installation to obtain the desired results.

Storm Water

The rainstorms that occur frequently during the winter months produce peak flows at the plant approximately four times the average dry season flows. The maximum flow recorded to date was 300 m.g.d., more than five times the average. This was recorded during the winter of 1952–3. The rate of sewage flow begins to rise immediately after rain starts to fall, indicating that the storm water is largely surface runoff entering the city sanitary sewers through yard drains, roof leaders, etc. This surface runoff carries with it into the sewer system abnormal quantities of silt, trash, sand, and debris, and also produces high sewer velocities, which scour out the sand deposits that gradually build up during normal flow periods.

This material, arriving at the plant, has caused breakdown of bar screens and grit collectors from overload, and the mixture of silt and sludge that is collected in the sludge hoppers of the sedimentation basins during these periods has not only been extremely difficult to pump, but also has caused rapid and excessive wear on the sludge pumps. Inspection of these pumps has shown that, while little wear takes place during the 9 or 10 months of the year when the sludge is free from silt and sand, pumps will wear so rapidly during the winter months that complete rebuilding is necessary to restore them to service.

During the past year the cities served by the plant have been conducting house-to-house surveys in areas where roof leaders and yard drains were known to be connected to the sewers. The member cities also have been carrying out large-scale programs of sewer separation, which when completed will separate all storm water from the system. This separation program will not be complete, however, for several years; in the interim the interceptor system and treatment plant will continue to receive increasing amounts of storm water. Furthermore, the problem of location of surface drains in an area of some 55,000 acres with a population of nearly 600,000 is of such magnitude that relief from the storm waters contributed from this source can be expected to be slow, with the limited personnel available for the work.

Industrial Wastes

The problem of the control of industrial wastes and the operational difficulties resulting from such wastes has been and will continue to be the major problem in connection with the operation of the treatment plant.

The plumbing codes of the cities, at the time of interception and treatment of sewage, were written with the idea of protecting the sewers only. Since sewage treatment was not contemplated when the ordinances were adopted, no special provisions were included governing the control of wastes detrimental to treatment plant operation. As a result, treatment of wastes prior to discharge into the sewers was practiced only when such treatment was profitable. To correct this condition, regulations governing the interception of sewage and industrial wastes were drawn up by the District and presented to the member cities with the recommendation that they be incorporated in the plumbing codes. These have been tentatively adopted by the city officials. Pending formal adoption of these regulations, however, the efforts of the field and laboratory staff have had to be directed toward the control of specific wastes that have had an adverse effect on plant operations.

Industries contributing waste to the plant include, among others; canneries; chemical companies; paint manufacturers; metal foundries, steel fabricators, plating works, machine shops, etc.; oil industries; soap manufacturers;

shipyards; food industries; laundries; meat packers and slaughterhouses; dock and port facilities; lumber companies; creameries and dairies; tanneries; wool processing; and cotton mills.

The types of wastes contributed range from small-volume low-strength wastes to large-volume highly concentrated wastes; from very slightly polluted wastes, such as barometric condenser cooling waters, to heavily polluted wastes, such as cannery wastes.

The two general classes of wastes most detrimental to plant operations have been those from the canning industry and those containing fats, oils, greases and waxes.

Cannery Wastes

The major waste, from a volume standpoint, is the seasonal cannery waste. During the peak months of August, September, and October 11 canneries discharge from 3 to 5 m.g.d. of waste into the sanitary sewers. During this period approximately 60 per cent of the total yearly cannery waste is contributed. These canneries process pickles, beans, potatoes, carrots, spinach, asparagus, sweet potatoes, squash, beets, peas, prunes, tomatoes, cherries, peaches, apricots, pears, and other fruits and vegetables.

The nature of the waste varies, depending on the material being processed, and ranges from the fairly clean low-load wastes from the processing of figs, to the turbid heavily loaded wastes from tomato and peach processing. The B.O.D. of these wastes has varied from 500 to 6,000 p.p.m.

The heaviest load results from tomato processing, which starts in August and continues through October. During this period 7 of the 11 canneries are processing tomatoes. Assuming an average B.O.D. of tomato wastes to be 1,600 p.p.m. (it is probably higher), and assuming the average daily flow of tomato waste to be 5 m.g.d., it may be calculated that the equivalent population of these wastes alone is approximately 400,000 persons, or roughly equal to the total connected population of the District.

During the month of September, 1952, the B.O.D. of the sewage at the booster pumping station in East Oakland, which receives a large part of these wastes, averaged 1,400 p.p.m., and the B.O.D. of the raw sewage at the treatment plant after dilution by domestic sewage averaged 460 p.p.m. The suspended solids, settleable solids, etc., were proportionately high.

During these months, some 8,600 cu. ft., or approximately 260 tons, of screenings were collected at the treatment plant bar screens. In one day alone, 35 tons of screenings were removed. These screenings were largely whole tomatoes and large pieces of tomatoes. Throughout the rest of the canning season signs of the other canning wastes were in evidence; however, their quantities never approached that of the tomato wastes.

During the tomato canning season, sedimentation efficiency was high and gas production increased to nearly 1,000,000 cu. ft. per day. In addition to the screenings load, however, the high solids loading resulted in the accumulation of quantities of tomato skins in the digesters. These skins still cause periodic plugging of recirculation and transfer pumps.

The load imposed on the treatment plant during this period, although roughly equivalent to that of a population of 1,000,000 people, did not affect the operation of the plant to the extent anticipated. Anticipated improvement in screening equipment by the canneries should materially reduce the burden imposed on the treatment plant by these wastes during the canning season.

Fats, Oils, and Greases

Of far greater importance from the standpoint of effect on plant operations have been the wastes containing fats,

oils, greases, and waxes. There are many sources of these wastes, among which are the following:

1. Two oil refineries, one dealing with used oils, the other with asphaltic oils.
2. A drum and barrel cleaning company, which cleans drums containing oils, greases, paints, lard, margarine, pigments, chemicals, and other materials.
3. Slaughterhouses and meat packing plants.
4. Food canneries canning meat products.
5. Soap companies.
6. A wool company.
7. Truck and automobile washing operations.
8. Oil storage facilities.
9. Cutting oils and lubricating oils from a variety of industries.
10. Garages and service stations.

The wastes contributed by these industries at any given time may contain almost any substance which could be classified as an oil, a fat, a wax, or a grease.

These materials either rise to the surface of the sedimentation basins in the form of heavy viscous scum, or settle out with the sludge. In either case, they ultimately enter the digestion system, and it is there and in the pipeline to the digesters that they have their effect on plant operation.

In the pipeline these greases adhere to the walls of the pipe to form a coating which quickly reduces its capacity to the point where complete cleaning by means of power-driven sewer rods is necessary. This condition has been found to be particularly severe during the winter months when the sewage temperatures are low. At times, weekly cleaning of the line, which is approximately 1,000 ft. long, is necessary to maintain operations. Consideration is being given to installation of heating equipment to preheat the sludge and scum to a temperature sufficient to keep the grease liquid while in the line.

In the digesters these materials form dense scum layers, which mixing and stirring have not been able to completely dissipate. Shifting of these dense scum layers in the digesters has recently been responsible for the breaking of the gas drawoff and scum breaker pipes in two digesters, allowing sludge to enter and completely flood the gas system.

These pipes are being replaced by external piping to preclude future breaks of this type. Connections also are to be provided to permit circulation of digesting material into this scum zone at additional points to aid in the control of the scum layers. These modifications are expected to improve and insure continuity of operation.

Typical Examples

The principal effort, however, is being directed toward control of the discharge of oily or greasy wastes into the sewers. This involves a long-range program of sampling and analysis of the wastes at the point of entry into the system and, in cooperation with the cities, inspection of the oil separators and grease intercepting facilities of industries likely to contribute such wastes. Although it has been slow, progress has been made in the control of these waste discharges, the action taken in a given case depending on the particular circumstances, as illustrated by the following cases.

Refinery Oil Reclaim

One industry that was contacted was discharging what was described as "slightly oily salt water" from spray condensing systems in a refinery. Samples of this waste were found to have an average oil content of approximately 5,500 p.p.m., equivalent to a daily discharge to the sewer of approximately 12,000 lb. of oil. Company officials when advised of the need for

removing this oil from the sewage, expressed concern over the fact that they were losing such large quantities of oil. The company rebuilt its oil separation system at a cost of $28,000 to provide more complete separation of oils from the waste waters. The oil content was thereby reduced to approximately 100 p.p.m., the waste now being discharged into a storm sewer, resulting in a substantial reduction in the sewer use charges paid by this company.

Drum Cleaning

Another case concerned the wastes from a drum cleaning operation. This particular plant cleans and repairs drums and barrels used as shipping containers in the oil, paint, chemical, and food industries. Oil, grease, and rust scale discharged by this plant caused periodic clogging of a large city sewer. Although the volume of the oily waste in this case was small, the concentration of oil and grease in the waste was as high as 97,000 p.p.m., or roughly 10 per cent. Although an oil separator had been built into the discharge line, it was far too small to handle the volume of wastes dumped from the solution tanks of the drum cleaning machines. When dumped, the wastes flowed through the tanks without separation.

When informed that the quanity of oil in the discharge would have to be reduced, this company retained a consulting engineering firm to study the problem and propose a solution. This has been done, and before long the necessary installations and equipment to collect and haul away this waste should be completed.

Lubricating Oil Reclaim

Another oil waste problem was solved in a somewhat different manner. This particular waste originated at a glass company, where jars and bottles were produced. The oily waste arose from the substantial amounts of oils and greases which dripped on the floors from the glass molding machines. When the floors were washed down, this waste flowed through oil separators to the sanitary sewer. It was determined that the capacity of the oil separators would be sufficient for good oil removal if the large quantities of clean unpolluted water used to cool the plungers in the glass molding machines were not discharged into the same separators, thus overloading them. It was recommended that the waste cooling waters be collected separately and discharged into the storm sewer, or else recirculated. Minor changes in the oil separators were also recommended. These recommendations have been acted upon, and the problem solved. In addition to removing oily waste from the sewer, these changes have also resulted in a substantial saving to the company in sewer use charges.

Recent analysis of the gas generated in the digesters revealed the presence of an aliphatic colorless oil. This oil was obtained by freezing it out of the sludge gas, using dry ice as a collant. The oily material has been tentatively identified as a naphtha-like material. Also evident in the condensate from the gas was a strong mercaptan odor identical with that usually associated with oil refineries. The implications of these findings are being investigated.

Chrome Wastes

Control of the discharge of chrome wastes from several small metal cleaning plants has also been effected. One such plant was built to clean and reclaim used artillery shell casings for the Army. One of the steps in this process involved immersion of the shell casings in a tank containing a diluted chromic acid solution, 4 lb. of chromic acid flakes being used in 400 gal. of water.

In this particular case, if discharged continuously the total amount of waste over any period of time was small.

However, the tank was dumped only when exhausted, and at the time of dumping the amount of chromium discharged to the sewer was excessive. It was recommended that these wastes be discharged into a dilution, or holding tank, diluted with other plant wastes, and then discharged slowly over a long period of time. These recommendations were followed by the company, and no unusual amounts of chromium have since been found in the sewer into which the wastes are discharged.

Colored Sewages

The presence of other wastes in large quantities has at times been indicated by the marked changes in color of the raw sewage. In one week shortly after the plant was placed in operation, a time when the industrial waste load was probably equal to or greater than the domestic contribution, blue, pink, and yellow sewages were observed. Some of these unusual colors have been traced back to their sources; others have not. The occasional reddish color in the sewage during April, May, and June has been attributed to the discharge of dye solutions used to color cherries.

At another time, a dark-blue sewage sample was collected from a city sewer. The source of this material was not definitely established. However, it was established that the color was due to an iron cyanide complex, either Turnball's blue or Prussian blue.

A large ink company presently discharges large volumes of colored wastes into San Francisco Bay. Plans are being made to connect these plant wastes to the EBMUD interceptor. At times, wastes of various colors have been observed to color the Bay water over an area about 200 yd. in diameter in the vicinity of the outfall—colors noted have been blue, green, red, pink, and yellow. These colored wastes probably arise from the washing of filters with kerosene. Consequently, in addition to the colors, the wastes contain appreciable amounts of solvents. At times, explosive mixtures of gases have registered on an Explosimeter used to test the atmosphere in the manholes along the sewer into which these wastes are discharged. As if this weren't enough, these same wastes have been found to have high B.O.D.'s and high suspended solids contents. It is hoped that the company will treat this waste, at least to the extent where it will not impose severe conditions upon the sewers or treatment plant facilities.

Wool Wastes

The wastes from a wool company have repeatedly been brought to our attention as a potential source of difficulties. The nature of this waste varies from time to time, but it generally has a B.O.D. of around 1,000 p.p.m., and a suspended solids content of around 1,500 p.p.m. The oil and grease content, mainly animal fat, has been as high as 55,000 p.p.m. The waste generally contains appreciable amounts of sulfide; values as high as 13 p.p.m. have been obtained. The pH of the wastes has varied from 2.7 to 10.4. In addition to the heavy load imposed on sewers and treatment facilities, as shown by the values given, the suspended materials in these wastes at times contain large amounts of animal fibers, which may be involved in the formation of plugs in the sludge lines at the treatment plant. The plugs, incidentally, are composed of about 55 per cent oil and grease, about 10 per cent fibers, and about 72 per cent total solids, of which some 75 per cent are volatile organic materials. Laboratory tests have shown that this particular waste could be vastly improved by effective screening and simple settling procedures. Negotiations are still under way to get this waste cleaned up.

Slaughterhouse Waste

Another industrial waste which is to be connected to the EBMUD collection system is the kill room waste from a slaughterhouse. These wastes are presently discharged into San Francisco Bay. Along the shore front immediately adjacent to that particular outfall, signs of pollution are observed which can be immediately laid to this waste. Such things as blood clots in large numbers, large amounts of grease, and bits of animal tissue are found along this shoreline. Laboratory and field tests show the average B.O.D. of the waste to be almost 3,000 p.p.m., the suspended solids content about 2,000 p.p.m., the settleable solids about 40 ml. per liter, and the total solids about 4,600 p.p.m., of which from 50 to 93 per cent are organic volatile solids. It is hoped that this company will treat its wastes in such a manner as to make them more acceptable as discharges into a city sanitary sewer. From laboratory tests it would seem that about one-third of the B.O.D. and a large amount of the suspended materials could be removed by efficient screening and settling.

General

One afternoon the influent channel and the sedimentation basins were suddenly coated with a thick layer of a bright yellow foam. Samples of this foam showed it to have a high chromium content. Although crews were sent out to try to trace back this waste, no definite conclusions were reached. However, the treatment section was notified not to put this particular scum in the digesters. This condition has not been repeated.

In this report, only some of the typical wastes encountered at the EBMUD sewage treatment plant have been described. Other wastes have been dealt with, some with satisfactory results, others where action is still pending, and a few where, for one reason or another, no headway has been made.

Summary

In summary, the problems encountered to date in connection with the operation of the treatment plant and interceptor system have not in general been of the type foreseeable during design. The problems involving equipment operation have resulted from the materials received during storms, from industrial wastes, or from special conditions not subject to analysis, such as those involving the check valves and chlorination systems previously described.

Plant operations will probably continue to be adversely affected by industrial wastes. Progress has been slow in the control of these wastes, due partly at least to the number of political jurisdictions involved and the lack of uniformity of local codes. The ultimate solution to this problem will be effected only by continued cooperation between all parties involved.

VACUATOR OPERATION AT SANTA MARIA *

By T. J. Mays

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The purpose of this paper is to present the results of a joint study on the part of The Dorr Company and the City of Santa Maria to determine the degree of purification resulting from the use of the Vacuator. A secondary purpose is to describe some of the unusual features of the Santa Maria sewage treatment plant.

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Prior to 1948, the Santa Maria plant consisted of a bar screen, two small clarifiers, and two small digesters. In 1948 a modernization program resulted in the installation of a 26-ft. diameter Vacuator, a 100 ft. diameter Biofilter, a 70-ft. diameter secondary clarifier having a side-water depth of 10 ft., and a 50-ft. diameter digester having a side-water depth of 22 ft. The two small clarifiers were combined into one primary clarifier and a wooden flume grit chamber was installed. A new grit chamber is to replace the present wooden flume in the future. Figure 1 shows these various features.

The average daily flow to the plant ranges from 1.0 to 1.8 m.g.d., with a maximum 24-hr. flow of slightly more than 2.0 m.g.d. Some industrial wastes consisting of vegetable packing wastes are received. These wastes consist of flows from the packing of tomatoes, celery, carrots, and spinach, with tomato wastes predominating.

The raw sewage enters the plant through a small manually-cleaned bar screen and flows through a wooden flume grit chamber and a Parshall flume, where the flow rate is recorded. The flow then passes through a Dorreo aerator, where it is subjected to a short period of aeration, and then to the Vacuator. The Vacuator-treated flow enters the primary clarifiers and flows on to the Biofilter. Pumps lift the filter effluent to the secondary clarifier, with about 20 per cent of the flow being recirculated to the primary clarifier. Flow to the Biofilter is at a fixed rate of flow of either 2,700 g.p.m. with a single pump, or 5,400 g.p.m. with two pumps. The actual amount of recirculation through the secondary system is controlled by a butterfly valve controlling the amount of flow from the final effluent junction box to the Biofilter. Final effluent is discharged either into a large earthen reservoir or directly into an open ditch to the fields. In either case it is used to irrigate alfalfa and pasture crops or sugar beets.

A novel method of digested sludge disposal is being employed in that a 6-in. line runs from the digesters to the effluent ditch, so that the digested sludge may be disposed with the final effluent. In this manner, the sludge is spread uniformly across the field under cultivation, where it is allowed to dry and then turned into the ground as fertilizer. Thus in one stroke the inconvenience of drying and handling

FIGURE 1.—Modernization of Santa Maria, Calif., treatment plant in 1948 included new Vacuator (center), Biofilter (center background), secondary clarifier (left), and digester (right).

sludge on the drying beds is eliminated and a simple method of distributing this valuable fertilizer is obtained.

A typical sectional elevation of the Vacuator is shown in Figure 2. The unit is a covered, cylindrical concrete tank with a central draft tube for the admission of sewage. The interior of the tank is maintained at a 9-in. vacuum by a small wet vacuum pump. Just before admission to the tank the sewage is aerated by a mechanical aerator or by other means, as described later. The small bubbles thus dispersed throughout the sewage flow attach themselves to suspended solids and under the influence of the vacuum rise within the Vacuator to form a thick scum. A skimming mechanism, operating continuously, removes the scum to a sump, from which it may be pumped to the digester. Material which is too heavy to float settles to the bottom of the Vacuator, where it is raked to a sludge sump and pumped to the digester. Clarified effluent is discharged continuously by means of a multiple take-off located above the bottom of the tank and connected to a seal chamber outside the vacuum area. Flow through the unit may be compared with the flow of a liquid through a spihon. No appreciable work is expended in elevating the flow to the water level of the unit, as this level is maintained by the vacuum. At the Santa Maria installation the water level is maintained by a floatless switch, which permits intermittent operation of the vacuum pump. The actual operating period is approximately 3 min. out of every 10 min.

In addition to the mechanical aerator previously described, tests were made with an air injection system consisting of two small centrifugal pumps and a specially designed educator. When this system is used a small amount of Vacuator effluent is returned through the air injection system, where it picks up the desired amount of small air bubbles, and from which it is discharged into the sewage flow entering the influent pipe of the unit. This system was found to be very flexible in that the amount of air and the size of bubbles could be controlled within certain limits.

Table I demonstrates the range of suspended solids removals obtainable with the various types of aeration employed in this study. During Periods 1 and 2, no aeration of any kind was employed. Even under these condi-

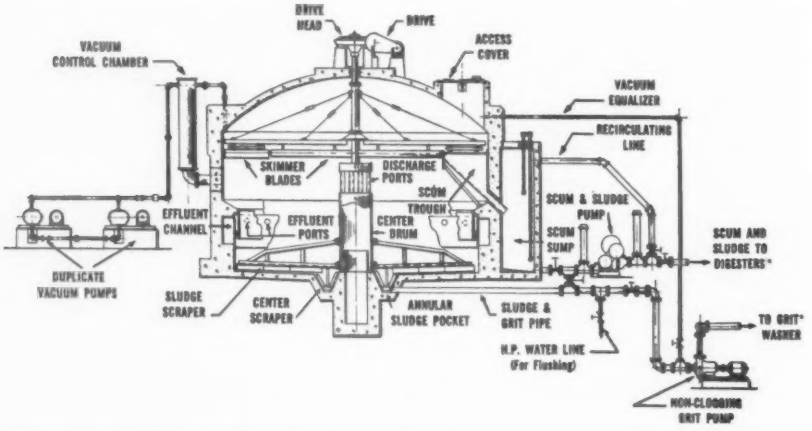

FIGURE 2.—Sectional elevation of Vacuator, with alternate arrangements shown for either scum and sludge removal or for scum and grit removal. (Courtesy The Door Co.)

TABLE I.—Effect of Type of Aeration on Vacuator Operation

Period	Aeration		Type of Sewage	Number of Tests (days)	Daytime Flow Rate (m.g.d.)	Suspended Solids			B.O.D.		
	Type	Rate (c.f.m./m.g.d.)				Infl. (p.p.m.)	Effl. (p.p.m.)	Removal (%)	Infl. (p.p.m.)	Effl. (p.p.m.)	Removal (%)
I	None	—	Domestic and tomato waste	3	1.35	340	257	24.4	294	263	10.1
II	None	—	Domestic	10	1.15	332	219	34.0	—	—	—
III	Mechanical	—	Domestic	7	1.20	477	280	41.3	340	269	20.9
IV	Diffusion	1.9	Domestic	5	1.31	418	252	39.6	304	181	40.5
V	Diffusion	1.9	Domestic and tomato waste	4	1.35	405	227	43.9	373	249	33.3
VI	Two-stage disp.	1.40	Domestic	14	0.99	371	164	55.7	—	—	—
VII	Single-stage disp.	2.48	Domestic	26	1.16	538	281	47.8	—	—	—

TABLE II.—Effect of Air Useage[1] on Vacuator Operation

Period	Air Used (c.f.m./m.g.d.)	Daytime Flow Rate (m.g.d.)	Suspended Solids			Settleable Solids			Settleable Solids, by Vol.			Number of Tests (days)
			Infl. (p.p.m.)	Effl. (p.p.m.)	Removal (%)	Infl. (p.p.m.)	Effl. (p.p.m.)	Removal (%)	Infl. (ml./l.)	Effl. (ml./l.)	Removal (%)	
1	2.28	1.17	451	195	56.7	263	60	77.2	16.2	3.0	81.5	10
2	1.31	1.15	387	178	54.0	213	48	77.5	13.2	1.9	88.5	46
3	1.12	1.03	355	181	49.0	174	41	76.9	11.9	1.5	87.4	18
4	0.71	1.09	342	198	42.0	176	64	64.0	10.6	2.0	81.0	16
5	0.37	1.15	368	224	39.1	179	59	67.0	12.3	3.3	73.5	12
6	0.00	1.15	332	219	34.0	165	72	56.4	11.7	3.9	66.6	10

[1] Using pump-eductor-pump system.

tions there was sufficient dissolved and dispersed air in the sewage to effect a 24 to 34 per cent removal of suspended solids from the sewage. In Period 3 the Dorreo aerator was employed with domestic sewage, resulting in a 41.3 per cent removal of suspended solids. During Periods 4 and 5, 19 c.f.m. of air per m.g.d. of flow was dispersed into the sewage entering the Vacuator by means of porous stone diffusers. Removals of approximately 40 to 42 per cent of the suspended solids were obtained under these conditions. Periods 6 and 7 show the removals obtained with the air injection method. Here, using very small air additions, most satisfactory removals of approximately 48 to 56 per cent of the suspended solids were obtained. Complete B.O.D. removal data were not obtained, but the removals ranged from 10 per cent with a 24 per cent suspended solids removal to 40 per cent B.O.D. removal with a higher suspended solids removal. A definite trend is evidenced, showing that the B.O.D. removal parallels that of suspended solids.

Table II relates the suspended solids removals and settleable solids removals to the quantity of air used when the air injection system was employed. Suspended solids removals ranged from 30.4 per cent when no air was used to 56.7 per cent when 2.28 c.f.m. per m.g.d. of flow was injected. At the same time the settleable solids by weight removals ranged from 56.4 to approximately 77 per cent. It should be noted that here again the removal increased with increased air injection. Settleable solids by volume removals did not show the same conformity as the other tests; nevertheless they were good, with removals averaging as high as 88.5 per cent over a 46-day period.

In conclusion it may be stated that the Vacuator, as operated at Santa Maria, has been a flexible and practically trouble-free unit capable of producing any desired removal of suspended solids up to about 55 per cent. Not only has it been simple and easy to operate, but its use also has greatly reduced the loading on the Biofilter and other units, resulting in a better effluent entirely satisfactory for the agricultural use to which it is put.

TIPS AND QUIPS

Uncomfortable Situation

Home-owners in Bryan, Ohio, perhaps may be excused if they protest vociferously over the treatment planned for them by the City Fathers, as expressed in a recent issue of the *Bryan Times* by the following:

"In the past the council had felt that the first thing they should do was to get the storm water out of the sewers before trying to force home-owners in. It was decided at last night's meeting that where the sewers could take the waste water without flooding, the owners should be told to get in now."

And thereby automatically become eligible for affiliate membership in SOWHESS (Society of Operators Who Have Experienced Saturation in Sewage).

New Pipe Wrench

A new wrench with a vise-like grip, and which cannot mar chrome pipe, is now available. The jaws are adjustable to accommodate pipe dimensions from ½ in. to 1¼ in., and can be fitted with hex inserts to handle nuts and bolts. The smooth-grip wrench needs no change of grip for tightening or loosening thread, yet will not slip or

scratch the surface of the pipe it holds. Robert Austin Corp., 51 Albany St., Boston, Mass., is the manufacturer.

Brochure Makes Good Public Relations Item

An extremely interesting 16-page brochure entitled "Sewage Treatment Works of the City of Easton, Pennsylvania" was recently published by the City of Easton Authority. The content includes a complete directory, legislative and historical background for the project, a flow diagram and description of the plant, and financing details.

Several excellent photographs give the reader a feeling of curiosity to see such a well-kept plant at first hand. Among the noticeable details are the architecture of the buildings and the landscaping of the grounds, both of which give the plant the appearance of a country estate. The concept and execution of the brochure entitle it to top rating as a public relations item.

Pipe Repair Clamps

A simple band type of clamp that facilitates permanent, quick, and easy pipe repairs is described in Folder No. 201, available from the manufacturer, Morris Coupling and Clamp Co., Dept. M–65, Ellwood City, Pa. The folder illustrates the method of installation and gives specifications and prices.

Classes for Employees Contacting Public

The total impression an individual has of a public service function, such as sewage collection and treatment, is usually based on day-to-day contacts made with employees who collect fees or taxes, perform services, issue permits, recruit and train employees, and handle complaints on services. With this in mind, the city of Glendale, Calif. recently conducted a series of classes for its employees who have contact with the public. Instruction was centered on how to maintain good public relations for the city while performing their jobs.

According to a report in the *Civil Service Assembly*, 84 city workers representing almost every division of the municipal government were given 5½ hr. of instruction in good telephone usage, handling of counter problems, letter writing, and operation of city vehicles. The course was designed to instruct employees on how to deal courteously and efficiently with the varied problems and types of people they encounter daily. Talks were given by both city officials and qualified outside speakers, training films were shown, the groups discussed realistic public relations problems, and each participant was provided with a mimeographed summary of the material covered.

Unsigned rating sheets turned in at completion of the course showed that three-fourths of those taking it considered the course very helpful and recommended that others should take it, the remainder feeling that the average employee would derive some value from the classes.

Have your public contact employees been given such a course? And if so, don't forget that a "quickie" refresher is needed periodically to keep the practical operation of the principles in mind.

Use With Care

A single ounce of a mosquito-killing chemical, called EPN, developed by the DuPont Company has been found sufficient to kill all the mosquito larvae in an acre of water-covered area. The powerful new mosquito larvicide can be used only in diluted form, however, and then only by technicians trained in safe application of poisonous materials.

The compound has proved particularly effective against DDT-resistant strains of mosquitoes. The commercial formulation—EPN 300 Insecticide—is a wettable powder to be mixed with water. It contains 25 per cent of the active chemical, and is applied at rates of 2.5 to 5 oz. per acre. Jeep-mounted sprayers have proved most satisfactory for applying the chemical, although successful applications have also been made by airplane. Dosages are carefully weighed and sprayers are meticulously calibrated to insure delivery at the proper rate.

The product is an organic phosphorus compound that has been used in apple and peach orchards for several years. Therefore its toxicity characteristics are well understood. It can be used without hazard, however, if applied under the supervision of competent personnel.

Conditions around sewage treatment plants—particularly as regards areas of standing or sluggish water in channels, lagoons, tanks, swamps, and low areas—might be such as to require use of the new larvicide where DDT-resistant strains of mosquitoes have developed. Extreme caution is advised, however, in its application.

Health Note

Don't work yourself to death by being careless at work.

Ice Remover

An ice removing chemical, known as X–73 Ice Remover, is said to melt ice and snow many times faster than salt, and to contain a rust inhibitor affording protection to automobiles, machinery, drains, and gutters. Produced in the form of coarse granules, the chemical is used by sprinkling lightly over icy surfaces and furnishes quick traction under spinning vehicle wheels. The ice remover is available in 100- and 200-lb. fiber drums and in waterproof paper bags from The Monroe Co., Inc., 10703 Quebec Ave., Cleveland 6, Ohio.

[As this is written we're having record-breaking heat and haven't had rain in longer than local farmers seem able to remember. Right now we'd settle for some of the ice we'll be trying to get rid of in a few months! —Ed.]

Overcooperative

We hope that the *Liberty* (Ind.) *Herald* was just indulging in a little inoffensive leg-pulling in its issue of July 9, 1953. In discussing problems arising at the Liberty sewage treatment plant, the paper said:

"At present the plant is operating satisfactorily and steps are being taken by the State Board of Health to correct this problem."

There's nothing like good teamwork to keep a superintendent on his toes!

Federation Affairs

REPORT ON RECOMMENDED PROCEDURES IN THE USE OF CHLORINE AT WATER AND SEWAGE PLANTS *

By The Joint Committee on Chlorine Supplies

August, 1953

The reason for formation of the Joint Committee on Chlorine Supplies may be found in the abnormal business relations experienced between users and manufacturers of chlorine during the hectic days of World War II and the postwar era. During this period the chemical industry experienced a phenominal growth. Demands for chemicals, including chlorine, were so great that service suffered, not as to quantity requirements, but as to the type of container unit furnished. Many plants wanting ton containers could not get them; they were obliged to use smaller package units. It was to study this and other related problems that the Federation of Sewage and Industrial Wastes Associations, through its Board of Control, in October 1950, established a special committee to study the problem. At that time a similar committee existed in the Conference of State Sanitary Engineers. The U. S. Public Health Service and various State Departments of Health were also active in trying to correct the situation.

In May 1951, all independent activities on finding a solution to the chlorine supply problem were joined with the formation of a Joint Committee on Chlorine Supplies. The members of the Joint Committee represented the AWWA, the Conference of State Sanitary Engineers, the U. S. Public Health Service, and the Federation.

In 1952 the Board of Directors of the Chlorine Institute, Inc., provided for the constitution of a Public Health Advisory Committee with a provision for a member of the following organizations to be represented on the committee without vote: American Public Health Association, American Water Works Association, Conference of Municipal Public Health Engineers, Conference of State Sanitary Engineers, Federation of Sewage and Industrial Wastes Associations, and U. S. Public Health Service. Fortunately, members of the Joint Committee were authorized to represent their organizations on the Public Health Advisory Committee of the Institute. Thus, a direct contact with the manufacturers was available and progress of the Joint Committee was facilitated, enabling completion of

* The Federation of Sewage and Industrial Wastes Associations, in printing this report, believes that the information contained therein is drawn from sources considered to be reliable. The Federation, as well as the members of the Joint Committee, make no guarantee, jointly or severally, of results; and assume no liability, jointly or severally, in connection with the information herein contained or the safety suggestions herein made. Moreover, it should not be assumed that every acceptable safety procedure is contained herein; or that abnormal or unusual circumstances may not warrant or require further or additional procedure. These suggestions should not be confused either with state, municipal, or insurance requirements, or with national safety codes.

this report. Although certain sections of the report were discussed with manufacturers' representatives, the responsibility for the report rests entirely with the Joint Committee.

The report has as one of its objectives the standardization of procedures in the use of chlorine in the sanitation field, such as the size of chlorine package to use; the inventory at users' plants; the return of chlorine containers, etc. To make such a program work, it needs application and cooperation between consulting engineers, public health engineers, executives and operators of water and sewage plants, and the chlorine manufacturers. The committee is hopeful that the recommendations set forth in the report will receive sufficient support to assure benefits to all concerned. Undoubtedly exceptions will be found to this procedural document, but they should be few.

The report deals with 11 separate subjects, as follows:

1. Conditions of use of chlorine cylinders and ton containers.
2. Chlorine inventories at water and sewage treatment plants.
3. Transportation of liquid chlorine.
4. Policy and practices in return of empty containers to chlorine suppliers.
5. Safety in the use and handling of chlorine.
6. Stand-by chlorination equipment.
7. Stationary bulk storage of liquid chlorine.
8. Procedure to be followed to secure chlorine in the case of an emergency.
9. Manufacturers of chlorinators and equipment for feeding hypochlorites.
10. Liquid chlorine producers and repackagers in the United States, Canada, and Cuba.
11. Producers of dry hypochlorites.

The information in items 9, 10, and 11 was furnished by The Chlorine Institute. It is correct to the best of their knowledge.

As a matter of information, the capacity for the production of chlorine gas in the United States has increased rapidly. In 1950 production was 2,372,500 tons per year and in 1953 production estimates are 3,467,000 tons of chlorine gas. About 50 per cent of the gas production is liquified for shipment. Liquid chlorine used for sanitation purposes in 1950 was 73,000 tons and in 1953 is estimated at 89,000 tons. These quantities represent 6.2 and 5.2 per cent of the total production of liquid chlorine for the years 1950 and 1953, respectively. Thus, sanitation chlorine is a minor production item to the industry. Its application in the sanitary field, however, represents one of the most important uses for chlorine—a use of chlorine which must be met irrespective of all exigencies.

It is of vital importance to the public health and welfare that the ever increasing demands for chlorine in the treatment of water and sewage and in other uses for sanitation purposes be met by expanding production as needed and by necessary adjustments in the methods of distribution of the chemical.

1. Conditions of Use for Chlorine Cylinders and Ton Containers

It is considered that rates of chlorine gas withdrawals should not exceed 40 lb. per 24 hr. for a 100- or 150-lb. cylinder, or 450 lb. per 24 hr. for a ton container. It is recognized that for short periods of time these rates may be exceeded (by as much as 50 per cent for a period not exceeding 2 hr.) and that under some circumstances with use of an evaporator, liquid chlorine can be drawn from a ton container to an evaporator at a rate much in excess of 450 lb. per 24 hr. The recommended uses of cylinders or ton containers are as given in Table I.

It is assumed that for continuity of operation on most water or sewage works or industrial wastes systems, spare cylinders and spare ton containers would be hooked up. This may

TABLE I.—Recommended Uses of Chlorine Cylinders and Ton Containers

Total Consumption (lb./24 hr.)	Maximum Withdrawal Rate (lb./24 hr.)	Recommended	Remarks
100	100	3 cylinders in use (possibly 6 connected)	
100	200	5 cylinders in use (possibly 8 connected)	
200	200	5 cylinders in use (possibly 8 to 10 connected)	Ton containers may be justified[1]
200	300	Ton containers[2]	1 carload would provide 150 days storage[1]
300 or more	300 or more	Ton containers[2]	1 carload would provide 100 days storage at plants with minimum (300 lb./day) rate of use

[1] Delivered by truck; carload lot delivery not usually justified.
[2] Some changes in this schedule may be required for seasonal users of chlorine.

mean that a special manifold should be ordered to permit connecting up extra cylinders or ton containers.

2. Chlorine Inventories at Water and Sewage Treatment Plants

In the final analysis the chlorine inventory at a user's plant must be predicated solely on the single objective that the treatment must not be stopped because of a lack of chlorine. Public health protection requires continuity of chlorination for water and sewage treatment plants alike. It must also be recognized that there is no known suitable substitute or alternate method for accomplishing disinfection of public water supply and sewage plant effluent. Thus an ample but practical inventory of chlorine at the user's plants is imperative. The question is, what is that amount?

The chlorine inventory needed at a water and sewage treatment plant can be determined by an analysis of the problem. The several factors that have a bearing on the problem are (a) the normal length of time required for delivery from shipping point to the user's plant, (b) the amount of chlorine used per day during periods of high requirements, and (c) emergencies which interrupt chlorine deliveries.

In an analysis of these criteria other factors immediately evolve—namely, the definition of inventory terms. By defining terms, understanding of the problem of chlorine inventory is greatly simplified. The terms that need definition are (a) critical inventory, (b) working inventory, and (c) maximum inventory.

Critical Inventory

Critical inventory of chlorine at a water or sewage treatment plant is defined as the number of unconnected (full) chlorine units equal to the number of units normally connected and in service. Except for systems using less than 5 lb. per day or for unusual circumstances, this type of inventory should not be condoned. A plant should be considered in emergency operation with this limited inventory.

Working Inventory

Working inventory of chlorine at a user's plant may be defined as that inventory which represents a reasonably ample supply to assure continuity of the disinfection treatment. In practice it should approximate (a) a duplication of the connected chlorine units (critical inventory), plus (b) a chlorine reserve equivalent to the length of time required for delivery from the shipping point to the user's plant (varies from 2 to 15 days supply

of chlorine, depending on local transportation conditions), and plus (c) a chlorine reserve for exigencies, strikes, transportation interruptions, etc. equivalent to a 15-day supply. The working inventory for any plant must be developed specifically for that plant, and be based on actual conditions.

Maximum Inventory

Maximum inventory is defined as that inventory which is equivalent to a 60-day supply of chlorine at the user's plant at normal rates of use. The small users of chlorine (5 lb. per day or less) must be excepted from this definition. Beyond the small plant there are few if any practical reasons to exceed the 60-day inventory. To do so ties up an unwarranted stock of cylinders and containers. Maximum inventories should be considered as being temporary only.

Recommendations

Regular chlorine shipping schedules or the placing of orders for chlorine should be developed or timed to maintain the chlorine inventories at the user's plants at approximately the working inventory as defined. In practice this objective may be difficult to obtain due to the size of chlorine deliveries, particularly where shipments are represented by carload lots. Thus, working inventories will vary in size; however, the extremes of these variations should be restricted between the critical and the maximum inventories. To maintain such a reasonable and well-defined inventory should prove advantageous to user and manufacturer alike.

Based on the foregoing definitions, Table II reduces to practical terms the critical, working, and maximum chlorine inventories for plants using chlorine at the rates of 0.5 to 2,000 lb. per day.

3. Transportation of Liquid Chlorine

Chlorine is shipped as a compressed liquefied gas in cylinders, ton containers, and single-unit tank cars. These three styles of containers are designed and built to the regulations and specifications of the Interstate Commerce Commission under a penal statute (62 Stat. 738).

The sizes of these styles of containers are as follows:

1. Cylinders

Cylinder capacities range from 1 lb. to 150 lb. of chlorine, but the 150-lb. size is most frequently used. Cylinders (usually known officially as ICC–3A480) may be shipped by motor and rail carriers in any quantity, subject to weight limitations. A minimum truckload lot weighs 23,000 lb. gross or 20,000 lb. gross in certain parts of the country, depending on territory truck tariffs. A 23,000-lb. truckload constitutes approximately 86 cylinders of 150 lb. net each. A minimum carload lot of cylinders weighs 30,000 lb. gross throughout the United States and constitutes approximately 110 cylinders of 150 lb. net each. The cylinder shells vary somewhat in weight; scales should be adjusted accordingly for each cylinder being used. The approximate tare weights of 100- and 150-lb. cylinders are as follows:

Net Cylinder Contents (lb.)	Approximate Tare Weight (lb.) (Lightweight Type)	(Heavyweight Type)
100	73	85
150	92	125

2. Ton Containers and TMU Tank Cars

The ton container, holding 1 ton of chlorine, may be shipped in any quantity on motor trucks or semi-trailers, subject to weight limitations, and the empty ton containers may likewise be returned. A special form of tank car, known officially as TMU (tank multiple unit), and the tanks, known officially either as 106A500 or 106A500 X, holding on an underframe 15 loaded or empty ton containers, may be shipped to a siding owned by the consignee or leased from the rail carrier by the consignee. This TMU tank car may,

TABLE II.—Recommended Chlorine Inventories at Water and Sewage Plants[1]

Average Chlorine Use (lb./day)	Critical Chlorine Inventory[2,3]	Working Chlorine Inventory[3]	Maximum Chlorine Inventory[3]
0.5	1 150-lb. cyl.	1 150-lb. cyl.	2 150-lb. cyl.
2	1 150-lb. cyl.	1 150-lb. cyl.	2 150-lb. cyl.
5	1 150-lb. cyl.	1 150-lb. cyl.	3 150-lb. cyl.
10	1 150-lb. cyl.	3 150-lb. cyl.	4 150-lb. cyl.[4]
20	1 150-lb. cyl.	4–5 150-lb. cyl.[5]	8 150-lb. cyl.[4]
50	2–3 150-lb. cyl.	8–12 150-lb. cyl.[5]	20 150-lb. cyl.[4]
100	3–5 150-lb. cyl.	16–24 150-lb. cyl.[5]	40 150-lb. cyl.[4]
200	6–8 150-lb. cyl.	30–47 150-lb. cyl.[5]	80 150-lb. cyl.[4]
300	1 ton cont.	4–6 ton cont.[5]	9 ton cont.[4,6]
500	2 ton cont.	8–10 ton cont.[5]	15 ton cont.[4,6]
1,000	2–4 ton cont.	12–18 ton cont.[5]	30 ton cont.[4]
2,000[7]	4–6 ton cont.	22–35 ton cont.[5]	60 ton cont.[4]

[1] 100-lb. cylinders are available. Where they are used instead of the 150-lb. cylinders, the net weight of chlorine in inventory should substantially agree with that shown.

[2] None of which is in use.

[3] Also represents the number of cylinders or containers usually in service. Local conditions could affect these figures materially. Irrespective of the number of units in service, the principle as expressed in the definition of critical inventory should still apply.

[4] Roughly represent 60 days of chlorine inventory.

[5] The smaller number represents the working inventory where deliveries require 2 days; the larger, represents the working inventory where deliveries take 15 days.

[6] Maximum inventories listed for these categories are for plants receiving chlorine delivery by truck. For plants receiving chlorine delivery by railroad car (15 1-ton containers) the maximum inventories should be 19 and 23 ton containers, respectively, for plants using 300 and 500 lb. per day.

[7] Users of 1 ton or more of chlorine per day should consider the use of single-unit tank cars.

under certain regulations of the Interstate Commerce Commission, be shipped to a nearby rail carrier track, the ton containers both loaded and empty being handled by the consignee. Rail carrier transportation of loaded ton containers, except on TMU tank cars, is prohibited. In the rail carrier transportation of TMU loaded tank cars, the weight for tariff purposes is the weight of the chlorine only. In the rail carrier transportation of empty ton containers, the TMU underframe must have 15 empty ton containers. As an alternative, empty ton containers may be returned in any number by rail carrier transportation or by motor carrier. Freight rates via motor carriers apply on the gross weight of the loaded ton containers, except where minimum quantity rates are in effect, in which case that minimum must be shipped. Special equipment is required for handling ton containers, whether delivered by truck or by rail. Stationary or movable cranes, or travelling overhead rail hoists, are necessary, along with some type of lifting rig.

3. Single-Unit Tank Cars

Single unit tank cars are in three sizes, holding 16 tons, 30 tons, and 55 tons of chlorine, respectively. All three sizes are in use in sanitation, the two smaller sizes being most of those in such use. A single-unit tank car must be consigned to and unloaded on a private or leased rail siding. The unloading of single-unit tank cars requires skill and should never be undertaken by other than trained personnel.

4. Tank Barges

Chlorine may, under regulations of the U. S. Coast Guard, be shipped in multi-tank barges. There are tank barges in use capable of transporting

up to 600 tons of chlorine. The unloading of such barges requires special skill and should be undertaken only after training under the direction of chlorine producers who have barges.

4. Policy and Practices in Return of Empty Containers to Chlorine Suppliers

Liquid chlorine shipping containers (100- or 150-lb. cylinders, 1-ton containers, and single-unit tank cars) represent sizeable funds invested by the manufacturers or suppliers of liquid chlorine. The interest on the total invested funds in 150-lb. chlorine cylinders or on containers, plus depreciation on containers and valves, must be included in the factory-door cost of producing and packaging liquid chlorine. Furthermore, when governmental restrictions on the uses of steel are in force it is difficult for chlorine producers and/or suppliers to procure additional containers.

It should be clear, taking these circumstances into account, that the larger the stock of containers a chlorine producer is required to own and maintain, the greater the factory-door cost of the packaged chlorine. Any group of chlorine purchasers which creates the necessity of producers maintaining a larger inventory of chlorine containers comprises the least attractive (profitable) class of purchasers of chlorine. More importantly, that group of chlorine purchasers which does not promptly return empty containers may well create a more consequential problem—namely, that of an insufficient number of containers on hand for the producer to completely fill orders in a single shipment. This creates confusion at both ends and adds to the producer's cost of supplying the chlorine user through splitting of shipments, extra bookkeeping, billing, etc. At the producers' end it likewise adds to cost of handling, record keeping, etc. At the same time, the chlorine user who neglects to return empty containers as promptly as is permissible is not showing consideration either for the supplier or for other chlorine customers, who may suffer the consequences of intermittent shortages of containers in the hands of the supplier.

During World War II the matter of empty containers in the hands of those responsible for operation of water and sewage plants became a problem of marked consequence. The pleas for more prompt return of empty containers, in smaller shipments than customarily practiced, bore fruit and relieved an increasingly serious situation. It behooves all users of liquid chlorine to reinstate the practice of prompt return of empty cylinders at regular intervals, regardless of the number available for return. When considering the numbers of water and sewage plants using chlorine, and multiplying this number by even a minor average number of returned cylinders per plant each month, the increase in the rate of cylinder turnover will result in an impressive accomplishment.

Concerning Seasonal Chlorine Users

In instances where chlorination is provided on a seasonal basis, such as sewage effluent chlorination during the bathing season or for the seasonal protection of shellfish areas, the tying up of chlorine containers may be particularly objectionable should the chlorination season end with a sizeable number of full chlorine containers on hand. In this instance the municipality has a dead investment in chlorine to be carried through the non-use months, valves are apt to deteriorate in dependability of operation, and fusible plugs in cylinder valves have also been known to deteriorate. Particularly undesirable is the dead investment in carry-over chlorine where the chlorine is being supplied in 1-ton containers —15 to the car.

Chlorine users in the seasonal category can do much to improve the con-

tainer turnover picture if they will look ahead a bit and place their final order of the season at a time, and in quantity, that will reduce the number of carry-over full containers to a minimum. Possibly, whatever remains at the close of the chlorination season can be transferred to the local water department or, if need be, sold to an adjoining community.

Where 1-ton containers are involved, the user may find it expedient to procure chlorine in ton containers for transportation by truck to finish out the chlorination season, rather than order another 15-unit car and tie up a number of these expensive containers during the non-chlorinating months. Second best would be the purchase of a less-than-carload shipment of chlorine in 150-lb. cylinders to finish out the season.

There may be other methods of providing a more rapid rate of chlorine container turnover in given situations than have been suggested herein. The whole point of this discussion is an attempt to prevail upon plant operators to practice the Golden Rule in the matter of keeping chlorine containers in mobile circulation for the benefit of all concerned.

5. Safety in the Use and Handling of Chlorine

It is essential for persons responsible for the procedures followed in the handling and application of chlorine at any installation to have a relatively comprehensive knowledge of the characteristics and properties of chlorine. It is not possible to establish a general set of rules or procedures that will assure safe use and handling of chlorine in all situations which may be encountered. For some situations, adequate safety will necessitate sound judgment and decisions based on a knowledge of the properties and effects of chlorine, and of the fundamental design characteristics of chlorine applicators and other appurtenances. It is believed that users should at least be familiar with the contents of the "Chlorine Manual" published by The Chlorine Institute, Inc., or an equivalent booklet published by a chlorine producer, and have a copy of either or both readily available for reference at all times.

General Recommendations

1. Only reliable men whose training in the handling of chlorine is commensurate with their responsibilities should be permitted to handle chlorine.

2. Chlorine and chlorinator rooms should be provided with adequate ventilation. In large installations, subsurface installations, or in buildings occupied by persons or containing equipment subject to chlorine attack, a separate and reasonably gas-tight room, equipped with mechanical ventilation which will change the air twice every minute, is considered essential and is required by some local and state regulations. Exhaust duct ports should be at floor level and ducts should terminate through a completely separate exhaust system to a location high enough to insure atmospheric dilution without endangering personnel or adversely affecting property in the area. Air inlets should be located across the room from exhaust ports, with the air of such temperature that it will not affect the chlorination equipment adversely. Shutoff valves should be provided near chlorinators if the connected chlorine containers are in a separate room or a considerable distance from the chlorinators. Switches for fans and lights should be outside the room, at the entrance. The vent hose for the chlorinator should discharge to the outside atmosphere, above grade.

3. A suitable number of gas masks of types approved by the U. S. Bureau of Mines should be provided and persons employed in the handling of chlorine should be trained in the use and

maintenance of the masks. Gas masks should be located outside the probable area of contamination so that it will be possible to reach them in case of emergency. Where chlorine is used over wide areas, masks should be available in several locations.

4. To test for chlorine leaks, attach a cloth to one end of a stick, soak the cloth with ammonia-water, and apply to the suspected area. A white cloud of ammonium chloride will result if there is any chlorine gas leakage.

5. As soon as there is any indication of the presence of chlorine in the air, steps should be taken to correct the condition. Chlorine leaks never get better; they always get worse if not corrected promptly. Solvay Emergency Devices, Kits "A", "B", or "C", should be available for stopping leaks in chlorine containers, and men should be trained in the use of such emergency equipment. Telephone the chlorine supplier or any chlorine producer if help is needed. Always wear a gas mask when correcting chlorine leaks. If a chlorine container is leaking in such a position that chlorine is escaping as liquid, the container should be turned so that chlorine gas escapes. The quantity of chlorine escaping from a gas leak is about one-fifteenth the amount that escapes from a liquid leak through the same size hole. At regular points of storage and use, emergency preparations should be made for disposing of chlorine from leaking cylinders or ton containers. Chlorine may be absorbed in caustic soda, soda ash, or hydrated lime solution. Caustic soda is recommended, as it absorbs chlorine most readily. The proportions of alkali and water preferred for this purpose are given in Table III.

6. Containers should be stored at a moderate temperature. Flames or direct heat should never be applied to a container. Chlorine containers connected to apparatus should be protected from a temperature higher than that of the equipment. When a number of containers are connected to the same manifold, chlorine will go from the warmer containers to the colder ones, which may result in filling some above the safe limit. Also, to prevent filling container above the safe limit, containers located at different elevations should not be connected to a common header. The heating of containers involves danger because the fusible plugs are designed to soften or melt at a temperature between 158° and 165° F. The corrosion rate of dry chlorine on steel is appreciably accelerated above 200° F.

TABLE III.—Recommended Alkaline Solutions for Absorbing Chlorine

Chlorine Container	Caustic Soda[1]		Soda Ash		Hydrated Lime[2]	
	(lb.)	Water (gal.)	(lb.)	Water (gal.)	(lb.)	Water (gal.)
100 lb.	125	40	300	100	125	125
150 lb.	188	60	450	150	188	188
1 ton	2,500	800	6,000	2,000	2,500	2,500

[1] 100 per cent.

[2] Hydrated lime solution must be continuously agitated with vigor while chlorine is to be absorbed.

7. Avoid dropping or bumping chlorine containers. Containers should be securely fastened to prevent tipping or rolling.

8. Valve protection hoods on cylinder and ton containers should always be kept in place except when such are being emptied. Do not hoist cylinders by the hood.

9. Keep valves of cylinders and ton containers closed at all times when not in service.

10. Store full and empty cylinders and ton containers in different places to avoid confusion. It is good practice to tag empties.

11. Use cylinders and ton containers in the order in which they are received. Cylinders and ton containers in active use should be located on a scale, so that the operator may know at all times

the amount of chlorine in the cylinder or ton container.

12. The following first aid measures are recommended for persons exposed to chlorine:

First Aid, 1. Carry patient from gas area. Patient should preferably be kept in a warm room (about 70° F.) Supply blankets if necessary. Keep patient warm and quiet. Rest is essential.

First Aid, 2. Place patient on back with head and back elevated.

First Aid, 3. **Call a physician immediately.**

First Aid, 4. Splashes of liquid chlorine and chlorinated water destroy clothing, and if such clothing is next to the skin will provide irritation and acid burns. In such cases, remove clothes and keep patient warm with blankets.

First Aid, 5. Carbon dioxide and oxygen mixture with not to exceed 7 per cent of carbon dioxide may be given. This mixture, ready prepared, and sold with the necessary apparatus, can be administered intermittently for periods of 2 min. followed by 2-min. rest periods over a total period not to exceed 30 min. Instructions of the purveyor of the gas apparatus should be carefully obeyed. If carbon dioxide and oxygen mixture is not readily available, oxygen alone may be used.

First Aid, 6. Milk may be given in mild cases as a relief from throat irritation.

First Aid, 7. If breathing has apparently ceased, start immediately the back pressure—arm lift method of resuscitation.

First Aid, 8. Provide first aid as may have been prescribed for emergencies by the company physician pending his arrival.

13. Use nothing but approved fittings for connecting chlorine containers. Never use pipe fittings on chlorine valves.

6. Stand-By Chlorination Equipment

The use of chlorination equipment in water, sewage, and related fields may be dictated for various reasons. These would include, among others, protection of the public health from transmission of pathogenic microorganisms, prevention of unpleasant odors, reduction of oxygen-consuming potential, reduction of gross bacterial populations, and chemical stabilization of certain products. The following recommendations concerning the provision of stand-by equipment relate only to that use of chlorination in which the protection of the public health is the reason for chlorination.

Stand-by equipment should be available in any installation where chlorination is practiced for the protection of public health and welfare. This applies not only to water treatment plants (at which chlorination would be used for the protection of public health), but also to those sewage and industrial waste treatment installations where chlorination of the effluent is demanded. Chlorination as used in sewage treatment for the protection of the health of the public might be directed toward the protection of a public water supply, of shellfish culture areas, and of bathing beaches. Determination of the need for protection in any instance rests with the responsible public health authorities.

In the small plant, whether it be for water supply, sewage disposal, or industrial waste treatment, requiring only one chlorinator for normal operation, one additional chlorinator should be provided for emergency situations. The size of the emergency unit should equal in capacity that of the basically required unit. In installations requiring two, three, or more chlorinating units in operation, stand-by needs should be met by providing a duplicate of the largest unit of the group to provide one unit more than is required for normal maximum demand. Consideration should be given in the original design to the desirability of using several small units providing flexibility not available with one or two large units.

Several general comments are made with regard to stand-by equipment.

Of equal importance to provision of stand-by equipment is the regular frequent servicing of all chlorinating equipment. Any stand-by equipment should be kept in perfect running order at all times. Borrowing of parts from stand-by equipment should not be permitted. A definite schedule of chlorinator use should include frequent routine operation of any stand-by equipment. Reliance on emergency equipment maintained by state health departments should not be considered as serving in lieu of stand-by equipment located at the installation itself. Possible availability of equipment from manufacturers should not be considered as meeting stand-by equipment needs. Knowledge of types of equipment used in nearby plants might prove of limited service at times when it might be possible to borrow a part of a chlorinating unit to replace a damaged or broken part.

No specific recommendations regarding stand-by equipment are made with regard to swimming pools. Although chlorination of pool water is practiced for the protection of the public, it is appreciated that the operation of swimming pools may be interrupted, thus providing an alternative to stand-by equipment in cessation of operation until repairs are made or until new equipment can be obtained. Hand-operated chlorination may sometimes be temporarily permitted. Whether stand-by equipment is provided is a matter of economics to be decided by the proprietor of the swimming facilities. Local or state health regulations and supervision should prevent the operation of swimming enterprises if adequate disinfecting facilities are not available for any reason at all.

Dependence on Power

Many chlorine feeders employed in the treatment of water supplies, sewage, or industrial wastes are dependent on power to operate pumps or provide auxiliary water or air pressure used in connection with the feeders. Where there is also need for power to produce the flow of water, sewage, or industrial wastes that is to be treated, the power for the chlorine feeder may be derived from the same source; an interruption of the flow is timed with the interruption of the chlorination. However, where the flow of the liquid to be treated is by gravity or where the source of power to produce the flow is from some other source than the source used to operate the chlorinator, failure of the electric or other power used to operate a chlorinator may cause interruption of the chlorine disinfection of the flow. A common practice is to install hydraulic pumps along with electric power to operate chlorinators, with the hydraulic pumps cutting in when electric power is interrupted.

In the air-operated chlorinators, air is usually provided by small, electrically operated compressors. Interruption of the flow of compressed air through power failure will shut down the chlorinators. To prevent such interruption of chlorination, an auxiliary source of compressed air is required. This may be provided by a gasoline engine driven auxiliary compressor or by a reserve supply of cylinders of inert gas, such as carbon dioxide. A minimum of two cylinders of carbon dioxide in service at the same time on each chlorinator is required to operate one chlorinator for a minimum of 10 hr. The use of high-pressure carbon dioxide presents an operational hazard. Such an installation should be made and operated only in accordance with the recommendations of the chlorinator manufacturer.

7. Stationary Bulk Storage of Liquid Chlorine

Stationary bulk storage of liquid chlorine is practical for large water and sewage plants under the conditions that (a) the storage tanks are of proper construction for chlorine service, (b) the storage tanks are

mounted so that the contents may be weighed at any time, (c) the tanks are well and properly maintained, (d) the quantity stored therein does not exceed safe loading limits, and (e) the loading and unloading practices are safe.

Hazards

The potential hazards of such storage are substantially the same as those of the storage of liquid chlorine in tank cars on water and sewage plant premises, differing only in that (a) unskilled maintenance of the storage tank may result in escape of chlorine, (b) overfilling of the tank may cause hydrostatic rupture of the tank and the complete discharge of its loading to the surrounding air, and (c) in the event of fire it will not be possible to move the stationary tank to a safer location.

Tank Construction

A specification for stationary bulk chlorine storage installations is being prepared by The Chlorine Institute, Inc. Reference should be made to the specification when it becomes available.

8. Procedure to Be Followed to Secure Chlorine in Case of an Emergency

The procedure to be followed to secure chlorine in the case of an emergency will necessarily be dependent on the general type of emergency which occurs. For the purpose of suggesting a routine procedure to be followed, emergencies have been separated into two types or categories and a procedure applicable to each is suggested.

(a) Inability to obtain needed normal chlorine requirements from suppliers.

The user should make a reasonable effort to obtain chlorine. Three or more suppliers should be contacted and requested to supply the requirements. In the event that there is advertisement for bids and no bids are received an inquiry as to why they have not submitted a bid should be made of the supplier or suppliers which have been filling the more recent orders.

If these efforts fail to obtain the necessary supply of chlorine, a request for assistance should be directed to the State Department of Health. The State Department of Health should if necessary, communicate the needs to the Surgeon General of the U. S. Public Health Service, Washington, D. C., with a request for assistance. Information accompanying this request should include the following:

1. Purpose for which chlorine is used.
2. Quantity used in the past year.
3. Estimated requirements during the next 12 months.
4. Quantity which it is desired to purchase at this time.
5. The name of the firm or firms which have filled the more recent orders for chlorine.
6. A description of the efforts made to purchase chlorine, including the name of the firms which have refused to fill orders and their reported reasons for not filling orders.

(b) A catastrophe or emergency which results in immediate need of much larger quantities of chlorine than are on hand or immediately available.

Prior planning and preparation is essential to efficiently cope with an emergency requiring greater quantities of chlorine than are normally available. As a general rule the executives of the local utilities or installations which are large sanitation users of chlorine, such as water and sewage treatment plants, will be a part of the local Office of Civilian Defense organization. Their civil defense responsibilities to provide safe water and waste treatment during an emergency will

include provisions to obtain needed quantities of chlorine.

Local agencies should initiate and carry out the necessary planning to assure that needed chlorine can be obtained. The following are believed to be essential components of such planning by the utilities.

1. An estimate should be made of the possible situations or conditions requiring the use of appreciable amounts of chlorine and the maximum quantity that may be needed.

2. A list of nearby stocks of chlorine should be developed. This list should include all organizations which usually maintain a stock of chlorine on hand, such as chlorine suppliers and repackagers, industrial users of chlorine, water plants, sewage plants, swimming pools, etc. With respect to each of these stocks the list should contain information on the type of chlorine or chlorine compounds available, the size of containers, and the quantity normally on hand which could be available for use in emergency.

3. As a corollary to chlorine supply, equivalent information should be obtained relative to chlorinating equipment which might be available for use in any emergency. Swimming pools might be a particularly good source of smaller sizes of chlorinating equipment, as frequently the pools may be inoperative or could be closed in an emergency.

In the event an emergency occurs, the following general procedure should be followed:

1. The local and state health departments should be immediately informed and requested to supply as much needed assistance as possible.

2. The supplies of chlorine and chlorinating equipment sufficient for the immediate needs should be obtained from those sources previously listed which can spare them at that particular time.

3. As soon as the immediate exigencies of the situation have been met and estimates can be made of the chlorine requirements for the duration of the emergency, or for a reasonable portion of the period it is expected to exist, orders should be placed with regular suppliers. These orders should be for the amounts required in excess of the quantities loaned or obtained from other stocks, plus whatever is necessary to replace that loaned, un-

TABLE IV.—Manufacturers of Chlorinators and Hypochlorite Feeding Equipment; June, 1953

State	City	Manufacturer	Type of Equipment[1]
California	Los Angeles	Paddock Pool Equipment Co.	C –
Illinois	Chicago	Everson Manufacturing Co.	C –
Maryland	Baltimore	Mathieson Chemical Corp.	– H
Massachusetts	Somerville	Precision Machine Co.	– H
New Jersey	Newark	Wallace & Tiernan Co., Inc.	C H
New York	Buffalo	Manzel Brothers Co.	– H
	Buffalo	Wilson Co.	– H
	Leroy	Lapp Insulator Co.	– H
	New York	Morse Boulger Destructor Co.	– H
Pennsylvania	Hatboro	Fischer & Porter Co.	C –
	Philadelphia	Milton Roy Co.	– H
	Philadelphia	Orchem Pump Co.	– H
Rhode Island	Providence	Builders-Providence, Inc.	C –
	Providence	Proportioneers, Inc.	– H
Texas	Dallas	Chlor-O-Matic Manuf. Co.	– H

[1] C = chlorinators; H = equipment for feeding hypochlorites.

TABLE V.—Liquid Chlorine Producers and Repackagers in the United States, Canada, and Cuba; June, 1953

State or Province	City	Producer or Repackager	Containers Filled[1]
		(*a*) UNITED STATES LIQUID CHLORINE PRODUCERS	
Alabama	Huntsville	Chemical Corps (leased to Nat'l. Distillers Products Corp.)	– – S
	Muscle Shoals	Chemical Corps (to be leased)	– – S
	McIntosh	Mathieson Alabama Corp.	– – S
Arkansas	Pine Bluff	Chemical Corps (leased to Diamond Alkali Co.)	– – S
California	Pittsburg	The Dow Chemical Co., Western Division	C T S
Colorado	Denver	Chemical Corps (leased to Shell Chem. Corp.)	– T S
Illinois	Monsanto	Monsanto Chemical Co.	C T S
Kansas	Wichita	Frontier Chemical Co.	C T S
Kentucky	Louisville	Goodrich Chemical Co.	– – –
Louisiana	Baton Rouge	Ethyl Corporation	– – –
	Baton Rouge	The Solvay Process Div., Allied Chem. & Dye Corp.	C T S
	Lake Charles	Columbia-Southern Chem. Corp.	C T S
Maryland	Edgewood	Chemical Corps (leased to Diamond Alkali Co.)	C T S
Michigan	Midland	The Dow Chemical Co.	– – –
	Wyandotte	Penn. Salt Mfg. Co.	C T S
	Wyandotte	Wyandotte Chemical Corp.	– – S
Nevada	Las Vegas	Basic Magnesium Corp. (chlorine plant leased to Stauffer Chemical Co. of Nevada, Inc.)	– – S
New Hampshire	Berlin	Brown Co.	C T S
New Jersey	Deepwater Point	E. I. duPont deNemours & Co., Inc.	– – –
New York	Mechanicville	West Vir. Pulp & Paper Co.	– – S
	Niagara Falls	E. I. duPont deNemours & Co., Inc.	– – –
	Niagara Falls	Hooker Electrochemical Co.	C T S
	Niagara Falls	International Minerals & Chem. Corp., Niagara Div.	– – S
	Niagara Falls	Mathieson Chemical Corp.	– T S
	Niagara Falls	Niagara Alkali Co.	C T S
	Niagara Falls	Stauffer Chemical Co.	– – S
	Syracuse	The Solvay Process Div., Allied Chem. & Dye Corp.	C T S
Ohio	Ashtabula	National Distillers Chem. Co.	– – S
	Barberton	Columbia-Southern Chem. Co.	C T S
	Painesville	Diamond Alkali Co.	C T S
Oregon	Portland	Penn. Salt Mfg. Co. of Wash.	C T S
Rhode Island	Providence	Fields Point Mfg. Corp.	C – –
Tennessee	Memphis	Velsicol Corp.	C T S
Texas	Corpus Christi	Columbia-Southern Chem. Corp.	C T S
	Freeport-Velasco	The Dow Chemical Co.	– – S
	Houston	Diamond Alkali Co.	C T S
	Houston	Ethyl Corp.	– – S
Virginia	Hopewell	Hercules Powder Co.	– – S
	Hopewell	The Solvay Process Div., Allied Chem. & Dye Corp.	C T S
	Saltville	Mathieson Chemical Corp.	– – S
Washington	Tacoma	Hooker Electrochemical Co.	C T S
	Tacoma	Penn. Salt Mfg. Co. of Wash.	C T S
West Virginia	New Martinsville	Columbia-Southern Chem. Corp.	C T S
	So. Charleston	Westvaco Chem. Div., Food Machinery & Chem. Corp.	– T S
Wisconsin	Kimberly	Kimberly Clark Corp.	– – –

TABLE V.—(*Continued*)

State or Province	City	Producer or Repackager	Containers Filled[1]
		(*b*) Canadian Liquid Chlorine Producers	
Ontario	Cornwall	Canadian Industries, Ltd.	– – S
	Sarnia	Dow Chemical of Canada, Ltd.	C T S
	Windsor	Canadian Industries, Ltd.	C T S
Quebec	Arvida	Aluminum Co. of Canada, Ltd.	– – S
	Beauharnois	Dominion Tar & Chem. Co., Ltd.	– – S
	Shawinigan Falls	Canadian Industries, Ltd.	– – S
		(*c*) Cuban Liquid Chlorine Producers	
Santa Clara	Sagua la Grance	Electro-Quimica de Sagua	C – –
		(*d*) United States Liquid Chlorine Repackagers	
Alabama	Birmingham	Wittichen Chemical Co.	C –
California	Duarte	Tops Chemical Co.	C T
	Los Angeles	The Dow Chem. Co., Western Div.	C T
	Torrance	John Wiley Jones Co., Inc.	C T
Colorado	Denver	Denver Fire Clay Co.	C –
Florida	Jacksonville	Jones Chemicals, Inc.	C T
	Tampa	Tesco Chemicals, Inc.	C T
Georgia	Atlanta	Tesco Chemicals, Inc.	C T
	Savannah	Coastal Chemical Co.	C –
Illinois	Chicago	Alexander Chemical Co.	C T
Indiana	Beech Grove[2]	John Wiley Jones Co., Inc.	C T
Iowa	Burlington	McKesson & Robbins	C –
Missouri	Kansas City	Thompson-Hayward Chem. Co	C –
New Jersey	Maple Shade	Pioneer Chloramone Corp.	C –
	Kearny	Marzahl Chemical Co.	C –
	Newark	American Oil & Supply Co.	C –
	Newark	E. M. Sergeant Pulp & Chem. Co.	C –
New York	Caledonia	John Wiley Jones Co.	C T
North Carolina	Charlotte	John Wiley Jones Co.	C T
	Thomasville	Tesco Chemicals Inc.	C T
Pennsylvania	Altoona	Western Penn. Chem. Co.	C T
	Lebanon	Lebanon Chem. Co.	C T
	Philadelphia	Penn. Salt Mfg. Co.	C T
	Philadelphia	Pioneer Chem. Works, Inc.	C T
South Carolina	Spartanburg	Moreland Chemical Co.	C –
Virginia	Rosslyn	Peebles Chemical Co.	C –
West Virginia	Belle	Belle Alkali Co.	C –
Wisconsin	Milwaukee	Hydrite Chemical Co.	C T

[1] C = cylinders; T = ton containers; S = single-unit tank cars.
[2] Indianapolis.

less other arrangements were previously made for replacement.

9. Manufacturers of Chlorinators and Equipment for Feeding Hypochlorites

As of June, 1953, the known manufacturers of chlorinators and equipment for feeding hypochlorites were as given in Table IV.

10. Liquid Chlorine Producers and Repackagers in the United States, Canada, and Cuba

As of June, 1953, the liquid chlorine producers and repackagers in the

United States, Canada, and Cuba were as given in Table V.

11. Producers of Dry Hypochlorites

Producers of dry hypochlorites known as of June, 1953, are given in Table VI.

TABLE VI.—Producers of Dry Hypochlorites; June, 1953

State	City	Producer
Michigan	Wyandotte	Penn. Salt Mfg. Co.
New York	Niagara Falls	Mathieson Chem. Corp.
Ohio	Barberton	Columbia-Southern Chem. Corp.

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Contributors

F. B. Elder, Amer. Public Health Assn.
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Reviews and Abstracts*

Centralized Sludge Treatment Featured in San Francisco Sewage Plan. By Ben Benas. *Civil Eng.*, **23**, 4, 38 (1953).

The sludge digestion and disposal facilities of the Southeast plant, which also handles sludge from the North Point plant, are described and a good flow diagram is shown. The process consists of thickening, primary digestion, elutriation, secondary digestion, two-stage elutriation, conditioning with ferric chloride, vacuum filtration, and drying. The starting of the digesters and problems on filtration and drying are discussed, but little data on sizes of units or operation results are given.

W. Hasfurther

Modifications in Aeration and Activated Sludge Process Offer Flexibility. By Gail P. Edwards. *Civil Eng.*, **23**, 5, 34 (1953).

A number of modifications of activated sludge treatment that have been used in full-scale plants or tested in pilot plants are briefly described. Flow diagrams are included for five, and average results, generally on the basis of sludge age, air used, solids concentration, and B.O.D. reductions, are included for eight modifications.

W. Hasfurther

Effect of Treatment of Domestic Sewage in Small Plants on the Counts of Faecal Bacteria. By L. A. Allen and Hazel M. Smith. *Water and San. Eng.*, **4**, 1, 6 (1953).

Samples of raw sewage taken on 13 occasions from seven large-scale sewage plants gave variations in *E. coli* (45,000 to 480,000 per ml.). The numbers of *Streptococcus faecalis* were lower but more variable than *E. coli*. Sedimentation reduced the *E. coli* count by 55 per cent and *S. faecalis* 61 per cent, but a much higher percentage (97.8 and 98.3 per cent reductions, respectively) was obtained by trickling filters followed by sedimentation.

A similar study conducted on five small sewage treatment plants (consisting of septic tanks and trickling filters) in general gave results similar to those obtained at the larger plants in respect to the relationship of the numbers of *E. coli* and *S. faecalis*. With one exception the counts in the septic tank effluents were somewhat lower than the average counts for settled sewage. The numbers of *S. faecalis* were reduced to a very low level by passage through a septic tank. A number of explanations are offered for the greater lethal effect of septic tanks on *S. faecalis*. H. Heukelekian

Air Pollution Abatement Manual, Meteorology of Air Pollution. Manufacturing Chemists Assn., Washington, D. C. 40 pp. Price, $0.75 (1953).

Chapter 8 of the manual, published in separate form for loose-leaf use, deals with the fundamentals and applications of meteorology in air pollution control engineering, the planning and interpreting of air pollution surveys, and plant site selection in relation to air pollution climatology.

H. P. Orland

Stream Sanitation in the Tennessee Valley. Tenn. Valley Auth., Chattanooga, Tenn. 23 pp. + 13 plates (1952).

This is a brief review of the stream sanitation picture in the Tennessee Valley, where the conditions and causes of pollution are already known to the extent necessary to provide a basis for beginning corrective action. H. P. Orland

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 325 Illinois Bldg., Champaign, Ill.

Melbourne and Metropolitan Board of Works, Report for Year Ended June 30, 1952.

The area served comprises 29 cities (including Melbourne) and 10 shires. The functions of the Board include the metropolitan supply of water and the metropolitan control of main drains and sewers and disposal of night soil, as well as planning for the Melbourne metropolitan area.

Considerable new work was done on the Upper Yarra water supply works, in part by day labor, including an earth and rock fill dam, diversion tunnel, outlet tunnel, etc.

The sewer system in the metropolitan area has been extended by 31 mi. of new sewers. The existing system was designed on the separate basis in 1892, and many parts are now inadequate. At present approximately 1,250,000 persons contribute to the system. Industrial wastes represent more than 16 per cent of the normal weekday flow and the amount of rain water entering the sewer system has reached serious proportions.

The metropolitan farm (some 26,073 acres located about 24 mi. from Melbourne) is still in operation. It receives about 67 m.g.d. (Imp.), or 95 per cent of the sewage of the entire area. In the year ended June 30, 1952, 3,786 head of cattle were sold, mostly for beef. In the year 4,010 calves were branded, the total number of cattle on hand on June 30, 1952, being 12,960.

New areas are being prepared for sewage irrigation. LANGDON PEARSE

Bactericidal Studies of Chlorine. By R. S. INGOLS, H. A. WYCKOFF, T. W. KETHLEY, H. W. HODGDEN, E. L. FINCHER, AND J. C. HILDEBRAND. *Ind. Eng. Chem.*, **45**, 996 (1953).

The article presents studies on the basic mechanisms of the action of hypochlorous acid, monochloramine, and chlorine dioxide upon amino acids and bacteria.

R. S. INGOLS

Residual Chlorine Methods and Disinfection of Sewage. By R. V. DAY, D. H. HORCHLER, AND H. C. MARKS. *Ind. Eng. Chem.*, **45**, 1001 (1953).

Because residual chlorine values may include a variety of chloramines whose bactericidal properties are unknown, it is necessary to run many tests on various samples for correlating residual chlorine and bacterial numbers. Data are given to show the correlation between residual chlorine values determined by both o-tolidine and two amperometric titration procedures with bacterial kill. The chlorine residual values by the amperometric procedure give a significantly better correlation with bacterial kill in samples with high organic matter concentration. The better correlation will generally permit a lower chlorine dosage. R. S. INGOLS

Destruction of Phenols by Oxidation with Ozone. By S. J. NIEGOWSKI. *Ind. Eng. Chem.*, **45**, 632 (1953).

Oxidation with ozone, when preceded in some cases by proper pretreatment, appears to provide an economical solution to the problem of destroying phenols in a variety of industrial wastes.

R. S. INGOLS

BOOKS, REPORTS, AND PAMPHLETS

Tentative Standard Specifications for Quicklime and Hydrated Lime (AWWA B202–52T). Amer. Water Works Assn. Price, $0.25 (1953).

Ohio River Pollution-Abatement Needs, Pittsburgh-Huntington Stretch. Ohio River Valley Water Sanitation Commission, Cincinnati, Ohio. 36 pp. (1953).

Report on a Biological and Chemical Investigation of the Waters in the Estuary of the Avon and Heathcote Rivers. By A. BRUCE. Christchurch (New Zealand) Drainage Board. Mimeo; 41 pp. plus maps, tables, and charts (1953).

Progress Report No. 33—Dec. 1, 1952 to Mar. 31, 1953. Washington Pollution Control Commission, Olympia, Wash. 46 pp. (1953).

Amer. Standard Specs. for Short-Body Cast-Iron Fittings, 3 In. to 12 In., for 250-P. s. i. Water Pressure Plus Water Hammer. (ASA A21.10–1952; AWWA C110–52). Amer. Water Works Assn. Price, $0.35 (1952).

Book Reviews

Pipefitters Handbook. By Forrest R. Lindsey. The Industrial Press, 148 Lafayette St., New York 13, N. Y. 282 pp. Price, $6.00 (1953).

Designed especially to answer field and shop problems involving pipe bending, layout, and installation, this practical handbook is a compilation of the author's notes gathered during many years of on-the-job experience. Included are fitting dimensions, measurements, angles, conversion factors, soldering and brazing, and a dictionary of piping terms.

The Municipal Year Book, 1953. Clarence E. Ridley and Orin F. Nolting, editors. International City Managers' Assn., Chicago, Ill. 602 pp. Price, $10.00 (1953).

The 1953 (20th) edition of this "must" compilation of municipal data contains 20 major tables presenting a vast amount of information regarding personnel, finances, governmental data, and activities of cities in the United States.

New sections of the 20th edition include those on economic classification of cities and metropolitan areas, management and financing data for city and city-county hospitals, statistics on special assessment financing for public improvements, and city activity in off-street parking. New data are included in the planning and zoning section for cities over 25,000 population.

In addition, most of the regular sections of the Year Book have been retained and brought up-to-date. As in previous years, articles in each field of municipal activity review the significant events of the past year and model municipal ordinances are given for each field.

Year by year the annual volume is becoming more valuable as a handy desk-top reference for comparison of municipal practices with those of other U. S. cities, not only for the top administrator of the municipality, but also for all departmental and bureau administrators.

Public Health Engineering. By Peter C. G. Isaac. E. & F. N. Spon, Ltd., 15 Bedford St., Strand, London, W. C. 2, England. 227 pp. Price, 36*s* net (1953).

This textbook is designed to supplement the author's lecture courses on the wide field of public health engineering, but is so written as to also provide the practicing engineer with an over-all appreciation of the place of his own particular branch in the composite picture. Included are four chapters on provision of an adequate supply of pure and wholesome water; five chapters on the collection, treatment, and disposal of the liquid and soil wastes of a community; and a chapter on the causes and prevention of ill health and discomfort due to aerial pollution. A chapter on district heating is included because of its connection with air pollution and water supply problems. American practice is described and compared with British practice wherever the author feels that the comparison may be of value to the reader, but the approach is always from that of prevailing British conditions.

The book is excellently illustrated and referenced.

H. P. Orland

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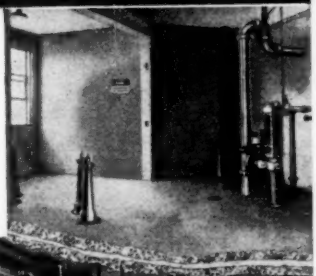
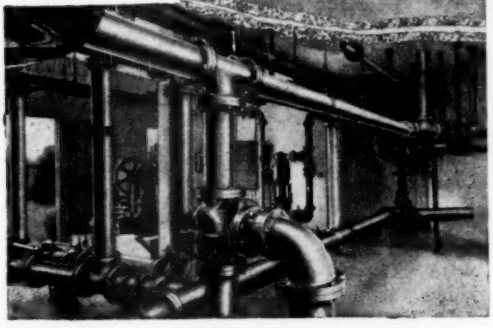
Two 75' dia. digesters with P.F.T. Floating Covers and the Control Chamber, completely above the ground surface, are shown at Orlando, Fla. Another example of CONTROLLED Digestion.



Control chamber is so arranged that piping is located on the ground floor, rather than below ground level. Piping at Orlando provides complete flexibility of operation—digesters can be used for two-stage digestion or for single stage digestion, depending upon the raw solids loading.



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Proceedings of Member Associations

NEW ENGLAND SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 1953 Spring Meeting of the New England Sewage and Industrial Wastes Association was held at Laconia, N. H., June 4–5, 1953. The meeting was attended by 107 members and guests.

Papers presented included:

"Problems Encountered in the Construction of Sewers," by a panel consisting of R. W. Erickson, Construction Manager, Sam Aceto and Co., Portland, Me.; S. P. Grasso, Public Works Superintendent, Milford, N. H.; A. E. Maynard, City Engineer, Nashua, N. H.; E. M. Thayer, General Manager, Sanford (N. H.) Sewerage District; and N. S. Stephens, Superintendent of Public Works, Portsmouth, N. H.

"Organization and Activities of the Water Pollution Commission of New Hampshire," by W. A. Healy, Director, Division of Sanitary Engineering, New Hampshire Department of Health.

"Program of Pollution Control on the Androscoggin River and Recent Legislative Action Regarding the Improvement of Waters in the State of Maine," by W. A. Lawrance, Bates College, Lewiston, Me.

"Classification of Streams," by S. G. Hess, Director and Chief Engineer, Interstate Sanitation Commission, New York, N. Y.

"Burlington, Vt., Sewage Treatment Plant," by P. F. Howard, Whitman and Howard Consulting Engineers, Boston, Mass.

"Meredith Sewage Treatment Plant," by E. B. Cobb, Metcalf and Eddy, Consulting Engineers, Boston.

"Design Features of the Laconia Sewage Treatment Plant," by J. S. Bethel, Metcalf and Eddy, Consulting Engineers, Boston.

"Operational Features of the Laconia Sewage Treatment Plant," by A. O'Mara, City Engineer, Laconia, N. H.

Inspection trips were made to the new Meredith and Laconia sewage treatment plants.

STEPHEN M. HURLEY,
Secretary-Treasurer

NEW YORK SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 25th Annual Meeting of the New York Sewage and Industrial Wastes Association was held at the Hotel New Yorker, New York, N. Y., January 22–23, 1953. Registration of members and guests totaled 298.

After presentation of the Dow Chemical Company motion picture "Air, Water and Industry," the following papers were heard:

"Measurements of the Respiratory Activity of Activated Sludge," by David B. Smith, Assistant Director, Engineering and Industrial Experiment Station, University of Florida, Gainesville, Fla.

"Sewage Treatment for Summer Resorts," by Olney Borden, Consulting Engineer, Liberty, and Edward B. Rodie, Assistant Editor, *Public Works Magazine*, New York City.

"Action Short of Treatment to Minimize a Chromium Waste Problem," by K. S. Watson, Coordinator of Waste Treatment, General Electric Co., Schenectady.

"The Use of Sulfur Dioxide in the Reduction of Chromium Wastes," by H. B. Channon, Manager, Technical Service Dept., Virginia Smelting Co., West Norfolk, Va.

"Instrumentation of the Chromium Waste Treatment Process," by W. N. Greer, In Charge, Electrochemical Sec-

(*Continued on page 396a*)

Lithographed on stone for U. S. Pipe and Foundry Co. by John A. Noble, A. N. A.

CAST IRON PIPE being unloaded as shown above may be for use in the city's water, gas or sewerage system. The more-than-a-century service record of cast iron pipe in this country is a strong reminder that the installation of this pipe will be not only for the benefit of the present generation but for many more to follow.

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tion, Leeds & Northrup Co., Philadelphia, Pa.

"Chromate Recovery by Ion Exchange," by C. F. Paulson, Special Applications Dept., Permutit Co., New York City.

"Use of Ion Exchange in the Recovery of Chromic Acid at Grumman Aircraft," by Durward T. Armstrong, Process Engineer, Grumman Aircraft Engineering Corp., Bethpage.

"An Evaluation of the Oxygen Consumed Test for Sewage and Industrial Wastes," by Hazel V. Roberts and Wallace W. Sanderson, Division of Laboratories, State Dept. of Health, Albany.

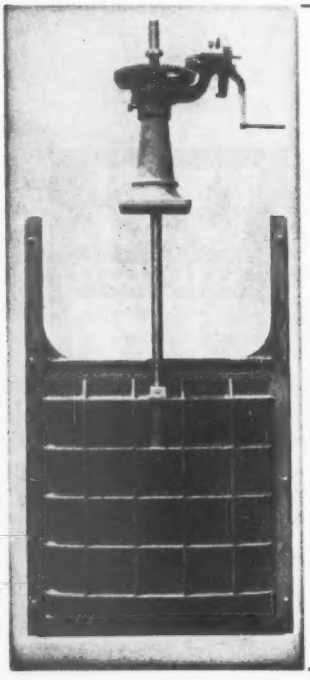
"Determination of Chemical Oxygen Consumed—A Rapid Dichromate Method," by Nandor Porges, Lenore Jasewicz, and Sam R. Hoover, Eastern Regional Laboratory, USDA, Philadelphia, Pa.

"A Rapid Chemical Procedure for the Estimation of Organic Materials in Industrial Wastes," by J. G. Niedercorn, Harold Senn, and Sumner Kaufman, Lederle Laboratories Div., American Cyanamid Co., Pearl River.

"Sludge Digestion," by a panel consisting of Harry E. Schlenz, Vice-President, Pacific Flush Tank Co., Chicago, Ill.; Uhl T. Mann, Superintendent, Ley Creek sewage treatment plant, Syracuse; W. L. Edwards, Superintendent, sewage treatment plant, Gowanda State Hospital, Gowanda; C. E. Irving, Superintendent, Bureau of Sewage Treatment, Schenectady; A. L. Wilcox, The Dorr Company, Stamford, Conn.; and Anton E. Sparr, Superintendent, Bay Park sewage treatment plant, Nassau County, N. Y.

At the Annual Business Meeting, A. J. Fischer was nominated to receive the Federation's Arthur Sidney Bedell Award. Officers elected for 1953 were:

(*Continued on page 398a*)



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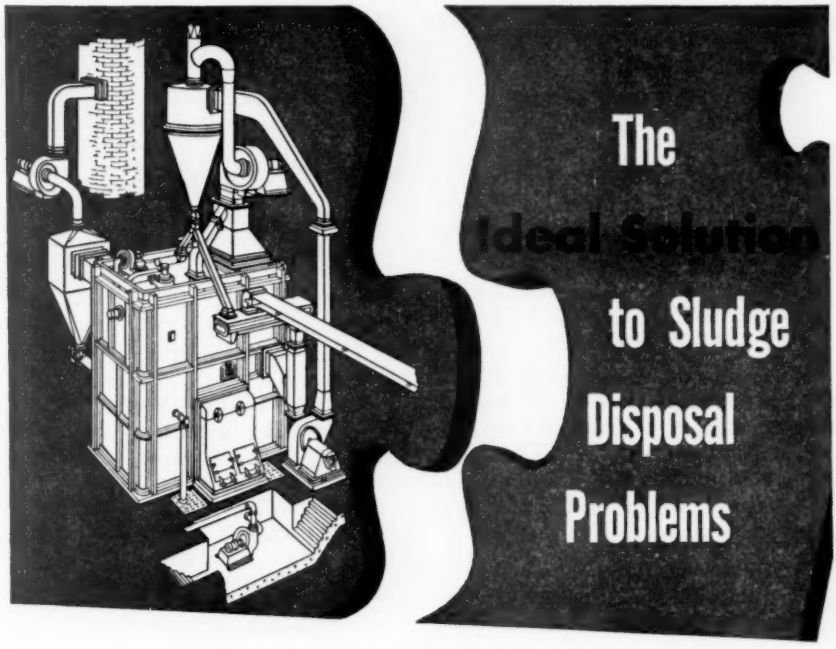

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Bethlehem, Pa.	Morris Knowles
Bloomsburg, Pa.	Gannet, Fleming, Corddry & Carpenter
Camden, N. J.	Havens & Emerson
Chicago, Ill. (W. Southwest)	City Engineering Dept.
Edgewater, N. J.	McClave & McClave
Fond du Lac, Wis.	Jerry Donohue Engrg. Co.
Houston, Texas	Greeley and Hansen
Lansing, Mich.	Drury, McNamee and Porter
Los Angeles, Cal.	Metcalf and Eddy
San Diego, Cal.	Frank Currie
San Francisco, Cal.	Clyde C. Kennedy
Schenectady, N. Y.	Havens and Emerson
Sheboygan, Wis.	Jerry Donohue Engrg. Co.
Washington, D. C.	Greeley and Hansen
Waterbury, Conn.	Malcolm Pirnie
Wyomissing Valley, Pa.	Albright & Friel
York, Pa.	Albright & Friel

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Secretary: R. C. Sweeney, White Plains.

R. C. SWEENEY,
Secretary

NEW JERSEY SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

A new all-time record attendance of 436 was established at the 1953 Annual Meeting of the New Jersey Sewage and Industrial Wastes Association, held at Atlantic City, N. J., March 11–13, 1953.

Papers presented at the technical sessions included:

"Impingement Aeration," by J. D. Walker and John R. Sperry, Walker Process Equipment, Inc., Aurora, Ill.

"New Gloucester Sewage Treatment Plant," by William Higgins, Superintendent, Gloucester (N. J.) Sewerage Authority.

"Biological Coagulation of Food Processing Wastes," by W. W. Eckenfelder, Jr., Consulting Chemist, Ridgewood, N. J.

"Theory and Performance of the Vacuator," by P. J. Cerny, The Dorr Co., Stamford, Conn.

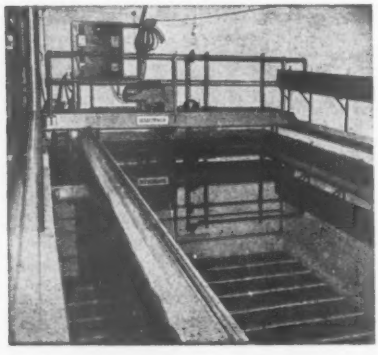
"Trickling Filter Studies on Fine Chemical Wastes," by Fred E. Reimers and U. S. Rinaca, Merck & Co., Inc., Philadelphia.

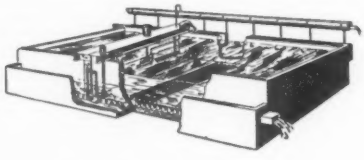
"Madison-Chatham Sewage Treatment Plant Improvements," by E. P. Molitor, Superintendent, Madison-Chatham (N. J.) Joint Meeting.

"Rex Tow-Bro Activated Sludge Treatment Plant," by W. N. Conrad, Chain Belt Co., Milwaukee, Wis.

"Water Works Improvements and

(*Continued on page 400a*)





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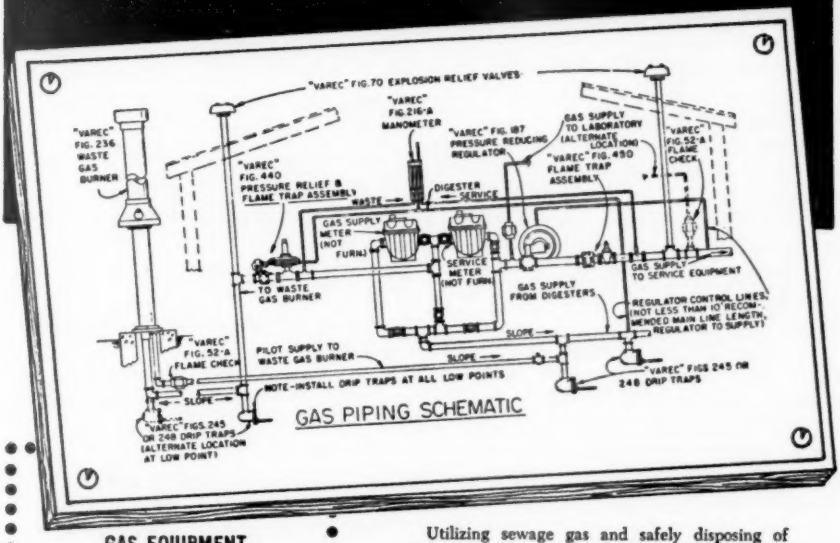
"VAREC" FIG. 70 EXPLOSION RELIEF VALVES
"VAREC" FIG. 236 WASTE GAS BURNER
"VAREC" FIG. 216-A MANOMETER
"VAREC" FIG. 440 PRESSURE RELIEF & FLAME TRAP ASSEMBLY
"VAREC" FIG. 187 PRESSURE REDUCING REGULATOR
GAS SUPPLY TO LABORATORY (ALTERNATE LOCATIONS)
"VAREC" FIG. 450 FLAME TRAP ASSEMBLY
"VAREC" FIG. 52-A FLAME CHECK
WASTE
DIGESTER
SERVICE
GAS SUPPLY METER (NOT FURN.)
SERVICE METER (NOT FURN.)
GAS SUPPLY TO SERVICE EQUIPMENT
TO WASTE GAS BURNER
GAS SUPPLY FROM DIGESTERS
REGULATOR CONTROL LINES (NOT LESS THAN 10' RECOMMENDED MAIN LINE LENGTH, REGULATOR TO SUPPLY)
"VAREC" FIG. 52-A FLAME CHECK
PILOT SUPPLY TO WASTE GAS BURNER
SLOPE
SLOPE
SLOPE
NOTE-INSTALL DRIP TRAPS AT ALL LOW POINTS
"VAREC" FIGS 245 OR 248 DRIP TRAPS
"VAREC" FIGS. 245 OR 248 DRIP TRAPS (ALTERNATE LOCATION AT LOW POINT)

GAS PIPING SCHEMATIC

GAS EQUIPMENT SPECIFICATIONS

a. **PRESSURE RELIEF AND FLAME TRAP ASSEMBLY**
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b. **FLAME TRAP ASSEMBLY**
"VAREC" Fig. No. 450

c. **FLAME CHECK**
"VAREC" Fig. No. 52A

d. **EXPLOSION RELIEF VALVES**
"VAREC" Fig. No. 70-1

e. **WASTE GAS BURNER**
"VAREC" Fig. No. 236

f. **DRIP TRAPS**
"VAREC" Fig. No. 245 (automatic)
"VAREC" Fig. No. 248 (hand operated)

g. **MANOMETERS**
"VAREC" Fig. No. 216A

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Utilizing sewage gas and safely disposing of excess gas is an automatic operation with "VAREC" Equipment incorporated into your sewage plant design. With this equipment, accurate gas pressures are maintained in all service lines. As soon as the digesters make more gas than required for service, the pressure relief valve to the waste gas burner opens to permit safe burning of the excess.

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Interest in Stream Pollution," by Charles H. Capen, Chief Engineer, North Jersey District Water Supply Commission, Wanaque, and R. E. Bonyun, Chief Engineer and Superintendent, Passaic Valley Water Commission.

"Sewage Treatment of New Jersey State Institutions," by H. E. Orford, Acting Chairman, Dept. of Sanitation, Rutgers University.

"New Developments in Chlorine Determination," by R. V. Day, Wallace & Tiernan Co., Belleville, N. J.

"New Walking-Beam Type Flocculator," by J. J. Horgan, R. B. Carter Co., Hackensack, N. J.

"The First 15 Years Are the Hardest in Operating a Chemical Coagulation Sewage Treatment Plant," by E. Arthur Bell, Borough Engineer, Essex Fells.

"Symposium on Sewage Treatment Costs and Financing Methods," by a panel comprising W. S. Foster, Engineering Editor, *American City Magazine*; Arthur D. Cross, Jr., Mount Holly Sewerage Authority; and W. S. Coward, Assistant Chief Auditor, Division of Local Government, State of New Jersey.

"Municipal Treatment Plant Problems with Industrial Wastes," by a panel comprising P. N. Daniels, Sanitary Engineer, Trenton; J. C. Albertson, Consulting Engineer, New York City; L. A. Greenberg, New Jersey State Dept. of Health; and C. K. Banks, Vice-President and Director of Research and Development, The Metal and Thermit Co.

P. N. Daniels, Sanitary Engineer for Trenton, N. J., was presented the Federation's Arthur Sidney Bedell Award. Other highlights of the meeting included an "Operators' Breakfast," the renowned "Speechless Dinner" (sponsored by the Water and Sewage Works Manufacturers' Association), and an exhibit featuring the equipment and products of 19 firms.

Officers, elected for a two-year term, were held over as follows:

President: S. Seid, New Brunswick.
1st Vice-President: J. W. Hood, Ridgewood.
2nd Vice-President: J. W. Collom, Bordentown.
Secretary-Treasurer: M. S. Kachorsky, Manville.

M. S. KACHORSKY,
Secretary-Treasurer

OHIO SEWAGE AND INDUSTRIAL WASTES TREATMENT CONFERENCE

The 27th Annual Meeting of the Ohio Sewage and Industrial Wastes Treatment Conference was held at the Mayflower Hotel, Akron, Ohio, on June 17–19, 1953. Registered attendance totaled 299, including 44 ladies.

(*Continued on page 402a*)

Nature's First Aid to Waste... ...Treatment
INCREASE SEWAGE PLANT CAPACITY WITHOUT CAPITAL COST!
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• BIONETIC is a dry powder of preserved beneficial groups of micro-organisms that accelerate natural biological action.
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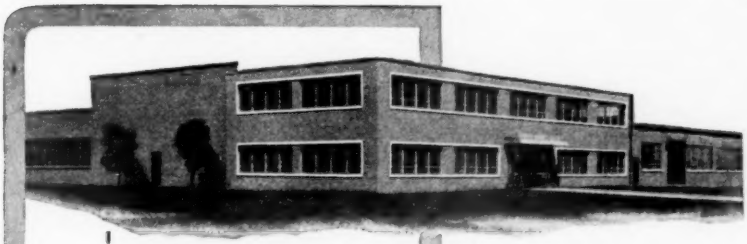

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in the design, manufacture and installation of process equipment for the handling and treatment of solids-in-liquid combinations

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WATER TREATMENT
SEWAGE & WASTE TREATMENT

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Papers presented at the meeting included:

"Aeration," by a panel consisting of J. D. Walker, President, Walker Process Equipment, Inc.; Paul M. Thayer, District Manager, Chicago Pump Co.; and G. E. Hauer, Chief Engineer, American Well Works.

"Ohio Water Pollution Control Board," by J. D. Porterfield, Director, Ohio Dept. of Health, and Chairman, Water Pollution Control Board.

"Review of Progress," by Walter Frye, Past President, Izaac Walton League, Wooster.

"Storm Water," by D. D. Heffelfinger, Engineer-Superintendent, Alliance.

"Operators' Forum," by a panel from the Sewage Plant Problems Committee.

"Municipal Progress," by F. H. Waring, Chief Sanitary Engineer, Ohio Dept. of Health.

"Operational Reports," by Ward E. Conrad, Assistant Engineer, Ohio Dept. of Health.

"Sewage Treatment—What and Why," by W. D. Sheets, Research Engineer, Ohio State University.

"Abatement Orders," by J. H. Blodgett, Superintendent, Sewage Treatment Plant, Columbus.

"Conservative Construction," by E. H. Wittmer, Sanitary Engineer, Ohio Dept. of Public Welfare.

"Financing Construction," by H. J. Crawford, Chief, Municipal Bond Dept., Squire, Sanders and Dempsey, Cleveland.

"Industries' Role in the Ohio River Program," by E. J. Cleary, Executive Director, Ohio River Valley Water Sanitation Commission, Cincinnati.

"Industry Progress Reports on Pollution Abatement," by a panel of representatives from eight major pollution-producing industries.

"Treatment of Oil-Bearing Wastes," by a panel comprising L. Corn, Gulf Oil Corp., Pittsburgh; W. Soden, Sun Oil Co., Philadelphia, Pa.; O. Zandona, Ashland Oil Co., Ashland, Ky.; and F. Eisele, Pure Oil Co., Heath, Ohio.

"Phenolic Wastes," by a panel comprising G. Dreher, Chemical Engineer, Jones & Laughlin Steel Corp., Pittsburgh; M. Dannis, Chemist, Armco Steel Corp., Middletown, Ohio; G. E. Muns, Manager, Fuel Division, Crucible Steel Co., Pittsburgh; and R. D. Hoak, Senior Fellow, Mellon Institute of Industrial Research, Pittsburgh.

"Metal Finishing," by a panel comprising industry representatives.

"Akron Improvements Since 1946," by Luther LaRue, Engineer, Division of Sewage, Akron.

"Environmental Health Center," by V. G. MacKenzie, Officer in Charge, USPHS Environmental Health Center, Cincinnati.

"Toxicity of Beryllium," by Carl S. Pomelee, Chief Research Chemist, Brush Beryllium Co., Luckey.

"Sewer Pipe Flow Coefficients," by K. W. Cosens, Associate Professor of Sanitary Engineering, Ohio State University.

Inspection trips were made to the Akron sewage treatment plant and to the Xylas Reclaim Division and Research Laboratory, Firestone Tire and Rubber Co.

Besides a fish fry at the sewage treatment plant, social events included several cocktail hours and a Smoker, courtesy of the Water and Sewage Works Manufacturers' Association. At the Annual Banquet, J. E. Gulick, General Manager of Tire Manufacturing, B. F. Goodrich Co., was the guest speaker.

Officers elected for 1953–54 were:

Chairman: W. D. Sheets, Worthington.
1st Vice-Chairman: G. A. Pettit, Middletown.
2nd Vice-Chairman: F. Ruck, Troy.
Secrtary-Treasurer: W. E. Conrad, Columbus.

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For 100 years engineers have depended on concrete pipe for sanitary and storm sewers. It has (1) strength to resist severe impact and sustain heavy overburdens, (2) durability to render long years of service, (3) a smooth interior that provides maximum hydraulic capacity and resists abrasion and (4) low annual cost.
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Flow Meters—Set of 7 new specification sheets (Nos. 241–7) covers electric and mechanical evenly-graduated flow meters, square root flow meters, and liquid level meters. Construction and engineering details are included.—Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Philadelphia 44, Pa.

Cast-Iron Pipe—A new 44-page catalog contains standard specifications and other useful data on double-X mechanical joint pipe in 3- to 48-in. sizes.—American Cast Iron Pipe Co., Birmingham 2, Ala.

Flow Controllers—New Catalog 1530 gives 56 pages of detailed specifications, control action descriptions, and ratings for both electric- and pneumatic-type ElectroniK measuring and control instruments. — Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Philadelphia 44, Pa.

Liquid Level Control—New electronic liquid level control utilizes capacitive action of liquid surrounding a porcelain-enamel-covered electrode that remotely operates the control unit.—Thermo Instruments Co., 1166 El Camino Real, Belmont, Calif.

Power Distribution—New 28-page power distribution manual (GEA–5900) and case history booklets (GEA–5896) give details of latest electric power distribution practices.—General Electric Co., Schenectady 5, N. Y.

Proportioning Pump—Newly redesigned controlled-capacity proportioning pumps operate on pressures up to 20,000 p.s.i., with capacities ranging from 5 c.c. to 128 gal. per hour.—Philadelphia Pump and Machinery Co., Wynnewood, Pa.

Chemical Feeder—Bulletin 30–K4 describes and gives detailed data on new low-rate dry feeder.—Omega Machine Co., 345 Harris Ave., Providence 1, R. I.

Butterfly Valve—A new type of butterfly valve for low-pressure service utilizes a replaceable neoprene seat to assure complete shutoff against pressure or vacuum, even with suspended solids in the controlled stream.—Keystone Tool Corp., P. O. Box 6716, Houston 5, Tex.

Waterproof Masonry Coating—A new, clear, silicone-base waterproofing material (Dascone) for masonry is described in literature giving specifications.—Dasco Chemical Co., Inc., 1602 Thames St., Baltimore 31, Md.

Conveyor Scales—New 8-page Bulletin 301 gives application data on conveyor weighing units.—Sintering Machinery Corp., Transportometer Div., Netcong, N. J.

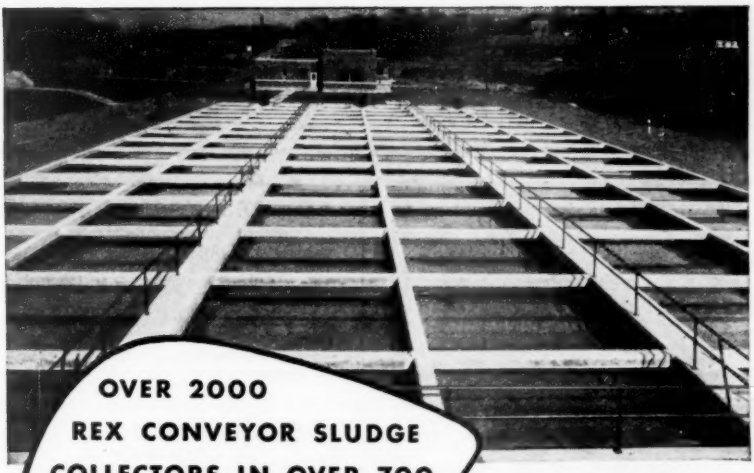
Turbidity Instruments—Bulletin 531 describes instruments for measuring and recording solution contaminants.—Ess Instrument Co., 96 S. Washington Ave., Bergenfield, N. J.

Pneumatic Butterfly Valves—Application data, specifications, and other details for pneumatic butterfly control valves are contained in Bulletin 8503.—Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Philadelphia 44, Pa.

Self-Scouring Venturi Tube—Designated as type VE, a self-scouring Venturi tube of elliptical section is now available for measurement of low-velocity, sediment-bearing liquids under a wide variety of pressures.—Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia 42, Pa.

Gear Motors—New 16-page information guide (GEA–1437H) describes the standard types of gear motors with ratings from ⅙- to 200-hp.—General Electric Co., Schenectady 5, N. Y.

Redox Potential Electrodes—Specifications and application data are contained in redox potential electrode Catalog 86–92.—Beckman Instruments, Inc., South Pasadena 1, Calif.



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★ ***Self-Aligning Bearings***—compensate for tank irregularities.

★ ***Centralized, Hardened Wearing Shoes***—eliminate splitting strains on wooden scraper flights.

★ ***Offset Split Drive Sprockets***—eliminate cantilevered brackets.

★ ***Double Life Sprockets***—chain engages every other sprocket tooth.

★ ***Drive Unit***—compact, totally enclosed. Shear pin protection.

★ ***Sub-Assemblies***—shop assembly of drive units and shaft assemblies assure proper alignment and fit.

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(Continued through page 411a)

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